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A PLAN FOR APPLICATION SYSTEM VERIFICATION TESTS

- THE VALUE OF IMPROVED METEOROLOGICAL INFORMATION -

VOLUME II

ECON INCORPORATED

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A PLAN FOR APPLICATION SYSTEM VERIFICATION TESTS - THE VALUE OF IMPROVED METEOROLOGICAL INFORMATION -

VOLUME II

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ECONOMICS OPERATIONS RESEARCH SYSTEMS ANALYSIS POLICY STUDIES TECHNOLOGY ASSESSMENT

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

LIST OF TABLES

LIST OF TABLES
(continued)

LIST OF TABLES
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5. COTTON GROWING ASVT (MISSISSIPPI)

5.1 Objective

The objective of the Mississippi ASVT is to demonstrate the practicality and value of frequent television broadcasts of SMS cloud imagery, radar images, current weather analysis, surface weather information and other weather advisories to specific agriculture user groups. Colorado State University is planning an experiment to demonstrate that television broadcast of SMS cloud imagery plus other related information can affect Mississippi farmer operations and decisions so as to significantly reduce crop production costs and losses due to meteorological events. Therefore, the Mississippi ASVT has as a further objective the conduct of an experiment which will monitor farmer decisions, actions, costs and losses, and meteorological forecasts and actual events and allow the economic benefits of satellite derived cloud imagery (and related data) and distribution technique to be ascertained.

It is the purpose of this section to establish a plan for the detailed design and conduct of an experiment which will yield measurements of the economic benefits which may be derived from satellite cloud imagery (and related data) and timely television distribution. Because of the diversity of farm products produced in Mississippi, it is necessary to select only those products and related farming practices for detailed study which may be impacted significantly by the timely availability of cloud imagery and other related data. Livestock and poultry have been ruled out for further study since it does not appear that their production related costs and losses will be significantly sensitive to the timely distribution of cloud imagery and related data, i.e.,

even perfect knowledge of the occurrence or nonoccurrence of rain during the ensuing 24 hours would not benefit the decisions and operations relating to these agricultural products in a manner measurable by a realistic economic experiment associated with the ASVT. Looking at the crops whose values represent approximately two-thirds of Mississippi's 1975 agricultural revenue, it can be seen that cotton and soybean clearly represent the major crops (see Table 5.1).

Based upon crop value and weather related costs and losses, it was decided to limit further consideration to cotton and soybeans. The 3.1 million acres in the Mississippi River Delta portion of Mississippi each year produces harvests of approximately 1 million acres of cotton, 1.6 million acres of soybeans and .5 million acres of the crop (cotton or soybeans) with the more favorable relative pricing. These two crops taken together represent a majority of Mississippi's agricultural land and an even greater portion of agricultural revenue.

Delta farming practices produce average yields per acre of approximately $500 for cotton and $125 for soybeans* with direct expenses being $200 and $40 per acre, respectively [17]. (Fixed expenses are excluded since it is likely that equipment purchasing trends will not be determined during the duration of the experiment.) The much smaller direct expenses associated with soybeans reflect the much lower level of input per acre (e.g., fertilizer, herbicides and insecticides) applied to that crop. Because of the relatively low cost of fertilizer, herbicides and insecticides, short lived and infrequent weather events have relatively

*These figures are for the Delta area whereas those in Table 5.1 are for the State of Mississippi.

Table 5.1 Major Mississippi Agricultural Crops [16]

Crop	Year	Harvested Acres (10^6)	Harvest (10^6)	Cash Receipts (10^6 \$)
Cotton	1974	1.7	1.6 bales	424
	1975	1.1	1.1 bales	TBD+
Soybeans	1974	2.5	46 bushels	335
	1975	3.1	69 bushels	TBD
Rice	1974	.11	4.5 CWT	45
	1975	.17	6.7 CWT	TBD
Corn*	1974	.11	≈4 bushels	2.1
	1975	.15	5.9 bushels	TBD
Wheat	1974	.16	3.9 bushels	14
	1975	.19	4.4 bushels	TBD
Sorghum	1974	.041	1.3 bushels	2.2
	1975	.038	1.3 bushels	TBD
Hay	1974	.64	1.1 tons	5.7
	1975	.65	1.2 tons	TBD

*Represents corn harvested for grain, excludes corn grown for livestock on individual farms.

+To be determined--not available at the time of this writing.

little effect on yield. Yield depends primarily upon seasonal weather patterns.

Since the cotton crop places a much greater reliance on heavy input farming practices, there is a commensurately larger benefit to be derived from improved accuracy and dissemination of weather forecasts. That is, a one percent reduction in direct costs will result in a larger per acre benefit than a similar change in the soybean crop. Therefore, it has been decided to concentrate on the cotton crop. Since the Delta

represents a preponderance of the total cotton production and features standardized farming practices, it has been selected as the test group area.

For reasons to be described in subsequent sections, the largest benefit to cotton farmers from the SMS and related information to be distributed via television is expected to arise from a reduction in the number of aerial applications of insecticides and herbicides which are "washed-off" by precipitation. Yield benefits resulting from more efficient (i.e., less wash-off spraying) may be small and, because of sampling problems, can not be reliably measured during the conduct of the ASVT. Since herbicides for soybeans (no insecticides) are also applied from the air, it may be possible, using ASVT results, to project a saving in that respect to the soybean crop; however, the remainder of this section is limited to developing a plan for an experiment for measuring the economic benefits from improved information made available to the cotton farmers in the Mississippi Delta area.

5.2 Farming Practices

Cotton and soybeans are the principle crops produced in the Mississippi Delta. Some rice is also grown, particularily in Arkansas. As in most areas of this size, soil types vary widely. In general, cotton is grown on the more sandy soils and soybeans on clay while the mixed soils may change crop from year to year depending on the relative prices of the two commodities. In 1973 cash receipts from crops and government payments for Mississippi totaled approximately $822 million for cotton lint, $327 million for cottonseed and $337 million for soybeans. The cotton was harvested from 1,340,000 acres and the soybeans

from 2,750,000 acres. As can be seen from the two maps of Figure 5.1, which indicates cotton and soybean acres harvested, cotton is more limited to the Delta region which has been outlined.

Successful germination of cotton requires a soil temperature of 65°F. for seven to ten days. Premature planting can therefore lead to a need for replanting which may mean that germination may be delayed for as much as two weeks. In addition, the portion of the crop which is not near maturity at the time of the first fall frost is destroyed. Therefore, it is necessary to optimally place the 180 days required to produce cotton within the 220 day (average) frost free period each year.

Cotton farmers begin soil preparation in the late winter and early spring as soon as the soil is sufficiently dry to permit field work. If the soil is too wet the ploughing machinery will pack the soil and create clods. If the soil becomes cloded, no planting can be done as the clods interfere with root penetration, watering and the introduction of the needed air and gases beneath the surface. As a result, cotton farmers will delay the ploughing process, even into early spring, if the soil is wet. Generally a farmer owns enough equipment to cover his entire area within the expected time frame. This means roughly one plow, planter and harvester per 500 acres. In order to insure total preparation the equipment will be operated as often and as long as possible stopping only when current weather and field conditions are prohibitive. In other words, if rain is expected within a few hours, the cotton farmer will begin work and continue work as long as possible rather than scheduling other activity for the entire day. Soil preparation generally extends from March until some time in April and includes several

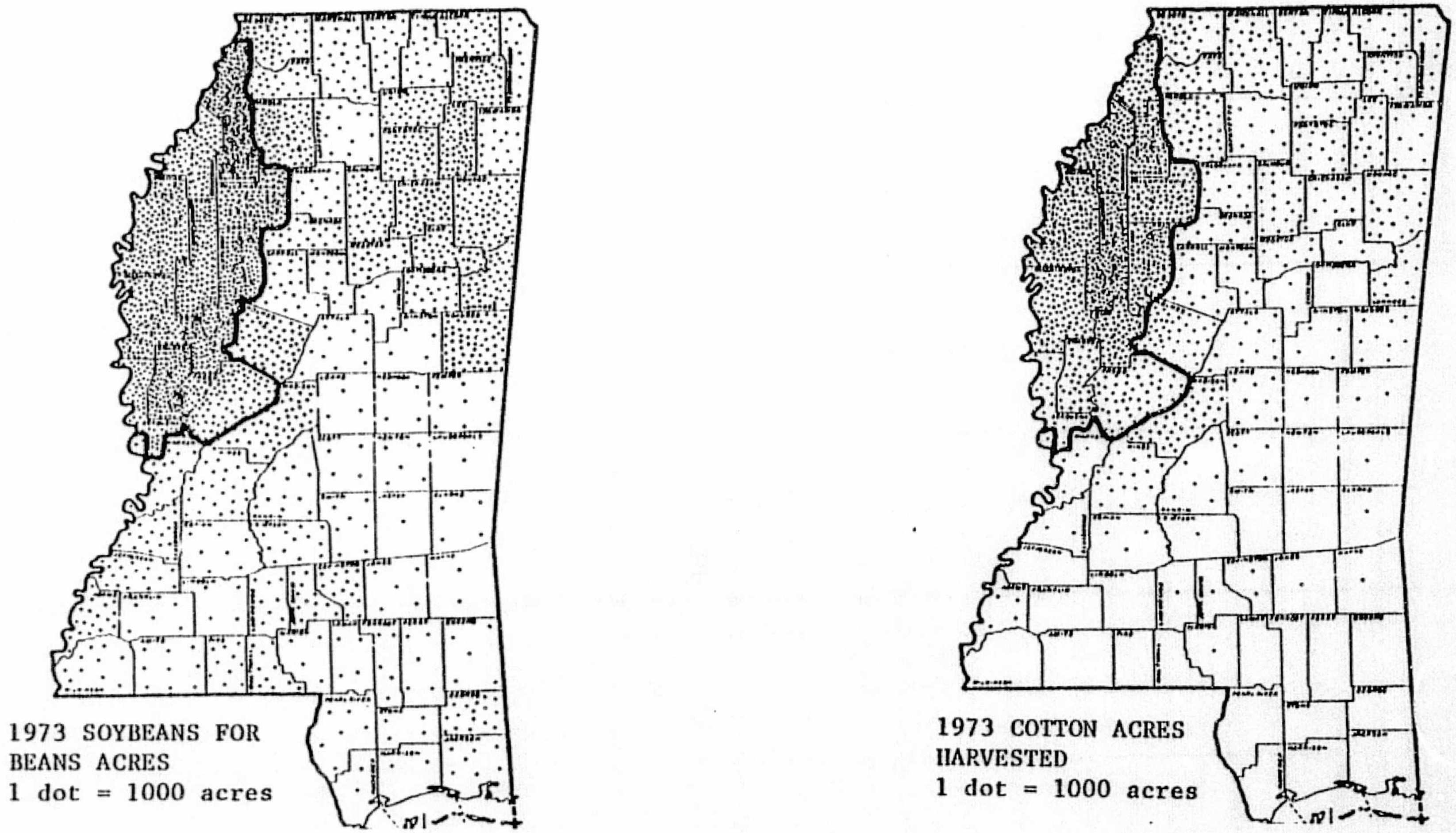

Figure 5.1 1973 Harvested Cotton and Soybean Acreage in Mississippi

(Source: Mississippi Agricultural Statistics 1954-1973)

distinct practices. Figure 5.2 illustrates typical costs for the various farm activities. The type and number of activities involved in soil preparation depends on the soil type and crop. If, however, the television dissemination of cloud imagery and other data provides information which allows the cotton farmer to complete these operations earlier and thus plant earlier, there may be economic benefits. However, to realize these benefits would require accurate long-range forecasts for a longer range period than that which may be effected by the television disseminated information. However, if accurate longer range forecasts were possible, the effect would be a lengthening of the growing season and presumably increased yields. Since cotton does require a long growing season, and because, generally, planting as early as possible is beneficial, economic benefits would arise from improved long-range (5 or more days) weather forecasting.

Planting is accomplished in much the same way in which soil preparation is carried out. Cotton is usually planted in 40-42" rows with the pattern sometimes altered by skipping one of every three rows or other variations. This is done to provide increased light to the lower sections of the plant. With the exception of requiring one and a half acres to plant the equivalent number of rows as usually found on one acre, farming practices in this type of planting remain much the same.

Forecasting may affect the planting depth of the seed since planting depth is a function of soil moisture, expected rainfall and temperature. If it is moist or rain is expected, the seed is planted more shallowly than normal. To significantly impact planting decisions

OPERATION DESCRIPTION	MONTH	TRACTOR DIRECT COST	TRACTOR FIXED COST	EQUIPMENT DIRECT COST	EQUIPMENT FIXED COST	LABOR COST	MATERIAL COST	MISC COST	TOTAL COST
		DOLLARS							
APPLY LIME X1/6	11	.00	.00	.00	.00	.00	.00	6.22	6.22
STALK SHREDDER 2 ROW	11	.70	.80	.05	.20	.69	.00	.00	2.44
CHISEL PLOW 16 FT	3	.63	.74	.15	.33	.51	.00	.00	2.35
CHISEL PLOW 16 FT	3	.63	.74	.15	.33	.51	.00	.00	2.35
DISK + INCOR 21 FT	3	.51	.60	.52	.96	.41	3.47	.00	6.47
DISK HARROW 21 FT	3	.40	.47	.34	.62	.32	.00	.00	2.15
FIELD CULT 21 FT	3	.28	.33	.14	.31	.23	.00	.00	1.30
DISK BED	4	.28	.33	.16	.27	.23	.00	.00	1.29
DISK BED + FERT	4	.34	.40	.23	.39	.78	7.44	.00	9.08
ROW CONDITION	5	.34	.40	.42	.81	.78	.00	.00	2.25
PLANT + PRE	5	.38	.44	.36	.80	.61	14.93	.00	17.52
TRAILER	5	.05	.05	.04	.08	.41	.00	.00	.63
CULTIVATE EARLY	5	.46	.54	.24	.45	.37	.00	.00	2.05
APPLY INS GROUND	5	.00	.00	.27	.34	.18	.81	.00	1.61
CULT + POST EARLY	5	.51	.60	.33	.64	.41	1.13	.00	3.63
CULT + POST EARLY	5	.51	.60	.33	.64	.41	3.65	.00	6.15
HAND WEED CONTROL	5	.00	.00	.00	.00	4.60	.00	.00	4.60
CULT + POST LATE	6	.37	.44	.24	.46	.30	3.65	.00	5.45
CULT + POST LATE	6	.37	.44	.24	.46	.30	1.75	.00	3.55
HAND WEED CONTROL	6	.00	.00	.00	.00	4.60	.00	.00	4.60
CULT + POST LATE	7	.37	.44	.24	.46	.30	7.10	.00	8.90
INSECT SCOUTING	7	.00	.00	.00	.00	.00	.00	1.50	1.50
APPLY INS AIR X2	7	.00	.00	.00	.00	.05	7.27	1.60	8.91
APPLY INS AIR X4	8	.00	.00	.00	.00	.09	14.53	3.20	17.82
APPLY INS AIR X2	9	.00	.00	.00	.00	.05	5.23	1.60	6.89
APP DEFOLIATE - AIR	9	.00	.00	.00	.00	.00	2.62	1.65	4.27
1ST PICK 2 ROW	10	.00	.00	12.63	21.48	3.45	.00	.00	37.56
HAUL	10	.00	.00	.00	.00	.00	.00	6.63	6.63
2ND PICK 2 ROW	10	.00	.00	5.48	11.02	1.77	.00	.00	19.28
HAUL	10	.00	.00	.00	.00	.00	.00	1.66	1.66
GIN	10	.00	.00	.00	.00	.00	.00	58.40	58.40
TOTAL SPECIFIED COSTS		7.14	8.36	23.56	41.06	21.35	73.57	82.46	257.50
INTEREST ON OPERATING CAPITAL									5.34
TOTAL SPECIFIED COSTS INCLUDING INTEREST ON OPERATING CAPITAL									262.84

Figure 5.2 Estimated Cost Per Acre, Solid Cotton, Sandy Soil, Usual Input Practices, 8 Row Equipment, Mississippi Delta, 1976

(Source: Cost of Production Estimates for Major Crops, Mississippi Delta, 1976, MAFES Bulletin 843)

longer term forecasts are required than it is anticipated will result from the television information dissemination. However, benefits will be accrued to the extent the new information will impact decisions.

If weeds become too large in size or numbers, the cotton yields are reduced by shading small plants (thus reducing growth which depends on light) and by competing for soil nutrients. Farmers therefore attempt to keep weeds small enough in relation to the cotton plant to avoid damaging yields. This is usually accomplished by a combination of mechanical methods and chemicals. Usually no weed control is needed in the latter part of the season (August and later) because the canopy of cotton plants shades the ground and controls the weeds.

A mechanical cultivator is run between the rows to remove weeds and may be accompanied by ground spraying. Cultivation like soil preparation is only sensitive to rain during the operation or soil that is too wet to support the equipment. Preemergent herbicide is applied during disking and/or planting operations. These chemicals are not particularily sensitive to rainfall. Many of them do require some rainfall within a week to 10 days to be activated. However, it is generally considered to take a large amount of rain to wash them away. If they are washed away it is also likely that the disking or perhaps planting will have been ruined and will need to be repeated. If so, herbicide may be reapplied.

Generally cultivation is accomplished about six times during May, June and early July. When the crop is extremely small cultivation is not accompanied by post emergent sprays, later it is. Post emergent herbicides are often applied in bands beneath the young cotton plants by

ground spraying equipment during the mechanical cultivation process. Here again some need rain to be activated. Others, however, are "contact kill" chemicals and if they have had an hour or so to dry on the weeds are not appreciably effected by rain. More accurate information could save applying herbicides and having them immediately washed off. Presently there is very little of this type of loss largely due to the short drying time required, and the farmers' accuracy in predicting rain within an hour. In addition, since the average ground rig covers about 16 acres per hour, one hour's loss is not as large a loss as one hour of spraying done by air. If wash off does take place it is uncertain whether or not reapplication will take place. This decision is normally based on several factors such as:

1. Time available to do the job: A farmer normally purchases enough equipment to service his area in a specified length of time. If the spray in a field is washed off the farmer may be able to redo it only at the expense of not doing another field at all, i.e., the service time constraint. This time constraint may be particularly limiting during rainy spells when field work is impossible. Note that if the farmer weighs all the factors, decides to reapply and is unable to get into the field, an air application of herbicide is still possible but is more expensive.

2. The situation of the weeds in the field at the present time: Obviously if the weeds are large enough to be damaging to the cotton, the farmer will be more likely to redo the operation.

3. The expected length of time before the field would normally be cultivated again: If it is scheduled to be redone in a matter of a few days the schedule may not be disrupted so as to do it immediately.

Insect scouts are used in both Mississippi and Arkansas to make weekly checks of a farmer's fields and indicate the number of insects in various stages within each field. Their report to the farmer includes the date the samples were taken, the field sampled, the number of eggs, larvae and insects found and recommended control

if necessary. The farmer uses this together with additional information on neighboring insect problems and weather conditions, and decides on the action to be taken. This process occurs on essentially a weekly basis from late June through September or until the cotton is ready to harvest. If however, the insect infestation in a given area is particularly bad, scouting and control decisions will be increased to every third day or so.

In Mississippi most scouting is done by professional entomologists on a private contract basis. In Arkansas, however, some of this scouting is done by an Extension Service Program which hires and trains college students to perform the tasks. (The only complaint with the program seems to be that students return to school before the insect season is completed.) Approximately 40 percent of the cotton farmers in the county visited (Jefferson County) participated in this program.

Usually insecticide treatment begins in June or July. The first application is usually applied to control thrips, insects which are only troublesome to cotton when the plant is very small. This can be applied either by ground or by air. Treatment for the later-season pests, bollworm and the tobacco budworm usually begins in late July. The first application is delayed as long as possible because this spraying kills off most of the beneficial insects in the field. As most of these insects have only one generation per season their pest controlling effect is not restored before harvesting.

Spraying decisions are made based on the life stage of the insects in the field. Eggs are laid on the terminal leaves of the cotton plants and develop into larvae in about five days. In the next

fifteen days or so the larvae grow and move down the leaves and stems to the boll. During this period they feed on the leaves and stems of the plant. Once they reach the boll they eat their way inside. They continue to feed and later drop to the ground as they mature and reach adult insect stage. It is during this late larva stage that the most severe damage occurs because (1) feeding damages the fruit of the plant, and (2) while they are inside the bolls, larvae are protected from normal insecticide treatment.

Two types of chemicals are used to control such insect problems. An ovicide depends on fumes to penetrate the egg and kill the unhatched larva. For this type of chemical to reach maximum efficiency about 12 rain-free hours are required after application. The actual efficiency achieved is a function of the drying time, temperature and the amount of precipitation received if rain does occur. Therefore if rain occurs six to eight hours after application, the farmer will not necessarily repeat the application.

The other type of pesticide used is the insecticide (for example, methyl parathion) which is effective against larvae and adults. It requires only two to three hours of drying time. A typical rule of thumb is that 1/4 inch of rain within two hours of application will negate the effects of "methyl." If this type of application is washed off, the farmer, in an effort not to allow adult insects to develop will generally reapply the treatment as soon as possible in order to be effective during the period of time when the larvae are exposed, i.e., they have not yet entered the bolls.

Ovicides and insecticides are most often applied simultaneously but can be applied separately if it is expected that rain will occur

after three hours but before 12 hours after application. Because of the speed of application this flexibility is more available in aerial applications.

As mentioned previously, the vast majority of spraying in Mississippi is by air whereas in Arkansas there is a mixture of both ground and air operations. The farmers who use ground rigs tend to use them whenever possible even at the end of the season when the cotton is quite high. If there is a period of rain, however, their problems are compounded. Rain not only may wash off insecticides but if the fields become sufficiently wet, immediate reapplication may not be possible. When this occurs the farmer has two alternatives. First, he can wait until the field is dry enough to work thus risking the possibility that the insects will become too large to control efficiently. Secondly, the farmer may hire an aerial sprayer to protect his fields. This may be quite difficult because generally during periods of rain and heavy insect infestation there is high demand for the air applicator's time. An air applicator will first service the needs of the farmers with whom he has season contracts. If the applicator has time remaining he will cover as many of those who normally use ground sprayers as he can. This can also cause damaging time loss to the ground rig user.

Those who use air sprays exclusively generally contract with an applicator to do all the spraying. Using the scout's advice the farmer calls the applicator and tells him what to apply. If rain looks likely, a decision must be made as to whether or not to apply the pesticide. This decision is usually made by the farmer with some input from the applicator, although the influence each man exerts in the decision process depends on the expertise and personalities of the individuals

involved. The cost of such a spraying service varies from about $.75 to $1.25 per acre as opposed to $.50 to $.75 per acre for spraying by ground methods.

The television information dissemination can be of great benefit in these spraying decisions. The primary benefit area would be in avoidance of having insecticides washed off. Farmers now estimate that they are having 1-2 sprayings per season (i.e. about 15 percent of applications) washed off by unexpected rain. If the television information dissemination could allow farmers to determine more accurately when rain will occur, then spraying may be delayed until after the rain. This will save the lost spray, the time required for reapplication and the incremental cost incurred if a stronger pesticide is required for reapplication. In addition to these benefits which accrue to the grower there will be certain societal benefits due to the reduced pesticide usage. The most direct of these is the reduced pollution due to reduced run-off produced by rain washing newly sprayed chemicals off the crop. The second type of societal benefit would be seen in a reduced rate of insect resistance build up. Insects which are treated with the same chemical over and over build up resistance to that chemical over a number of generations and eventually can no longer be efficiently controlled by that chemical. The less a chemical is used, the slower this process becomes, thus allowing the use of chemicals of lower toxicity for a greater period of time.

In addition, if by looking at the televised maps, the farmer is able to determine that predicted rain will not affect his fields, he may be able to apply a spray he would not ordinarily use and thus avoid having to use a more expensive spray for larger insects. Another type

of benefit in spraying may result from more efficient scheduling of pesticide applications. If an aerial applicator is able to predict more accurately which areas are going to receive rain during the day, the applicator may be able to schedule fields away from this area rather than having to fly to an area, discover rain and have to spend time moving to another area.

The harvesting operation involves two distinct actions, first defoliation and then the actual picking of the cotton. Once 50 percent of the bolls are mature, a chemical defoliant is sprayed on the cotton to remove the leaves and allow the mechanical pickers to harvest only the bolls. (If there are leaves or dirt in the cotton lint it is judged a lower grade and sells for a lower price.) The defoliant spray is applied the same way as insecticide and requires about 8 hours to dry effectively. Noting the pertinent simularities, it is expected that benefits will be realized in much the same fashion in both types of sprays although the magnitude of this benefit will be less since the defoliant cost is significantly less. When the leaves have fallen harvesting begins. Generally a farmer works as often as weather and field conditions permit until harvest is complete.

5.2.1 Geographical Distribution

5.2.1.1 Distribution of Soil Types

The Mississippi and Arkansas Delta soil vary from clay to sandy soils. The distribution between clay, mixed and sandy soils follows no particular pattern. That is, one is not found strictly along the river or in any other specific pattern. Variation takes place on a very small scale so a single farmer is likely to have all

the basic soil types represented in at least one (and probably more) of his fields.

Soil maps indicate large numbers of small areas of Alfisols and Inceptisols and some (fewer) small areas of Entisols in the Delta area. As far as an experiment is concerned, it seems likely that it will be possible to randomly sample on the basis of soil type or to sample on other criterion first to select the individual farmer involved and then select the required distribution of sandy and mixed soils from the fields of those farmers already chosen. Note that clay soils will most likely be excluded from the distribution because cotton is not generally grown on these soils since they are much better suited to soybean production.

5.2.1.2 Meteorological Distribution

The meteorological distribution of Mississippi is relatively uniform as can be seen from Figures 5.3-5.7 which present isoline maps of normal annual precipitation and temperature (1941-1970), median dates of last and first spring freezes and the average length of the freeze-free season (1954-1973). The greatest variation in each of these occur in the southeastern gulf region and in pockets located in the more hilly eastern section of the state. The main cotton growing area, i.e., the Delta region is extremely homogeneous with normal annual precipitation ('41-70) about 50 inches, 64 degress F normal annual temperature ('41-70) and an average of 230 freeze-free days per season ('54-73). According to the Climatic Atlas of the United States the adjacent regions of Arkansas show the same climatic patterns.

This is not to say, however, that the day-to-day weather conditions within Mississippi or the entire Delta area do not vary. Days

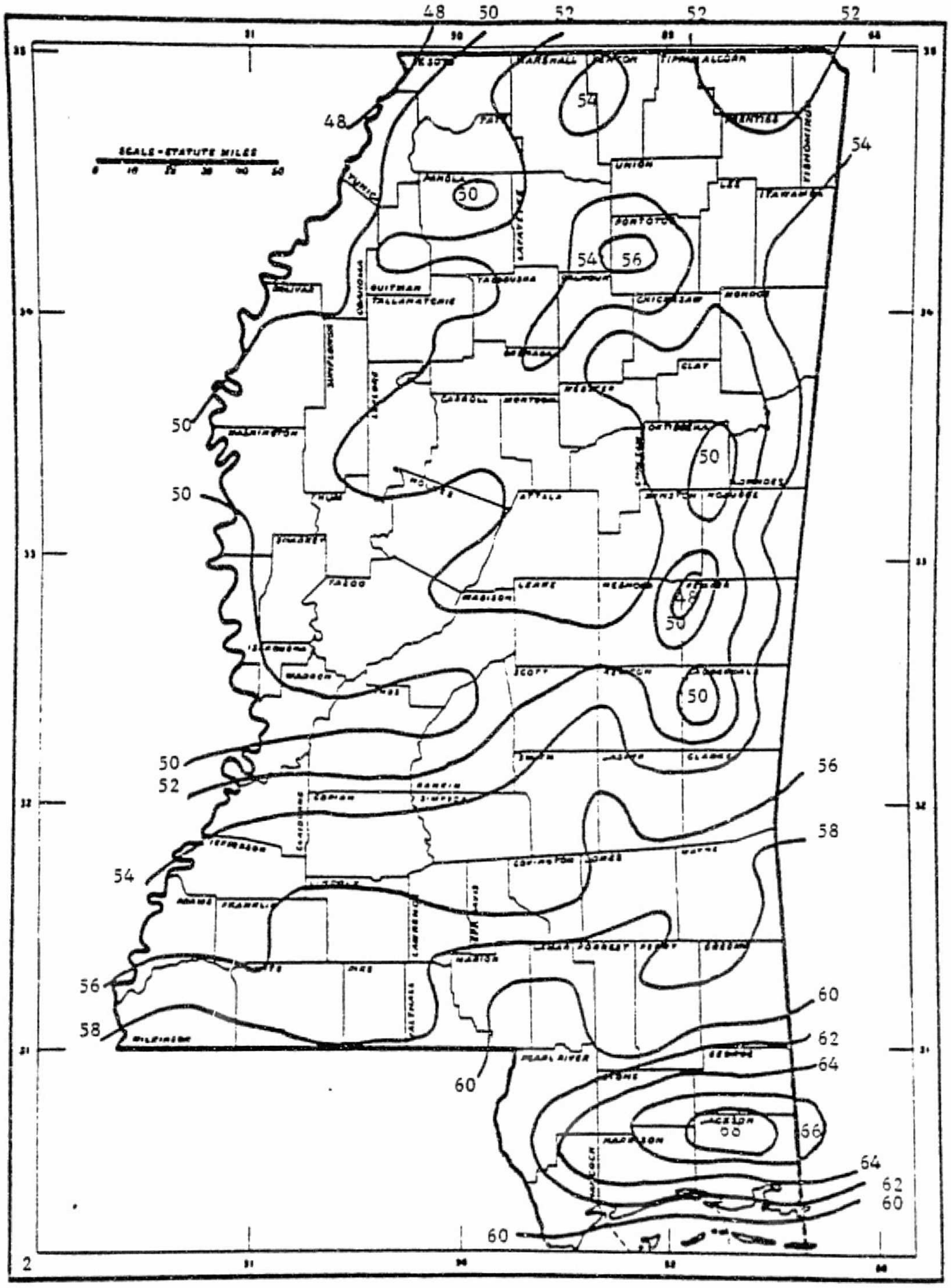

Figure 5.3 Normal Annual Precipitation 1941-1970 (inches)

(Source: Mississippi Weather and Crop Report 1966-1975, Mississippi Crop and Livestock Reporting Service)

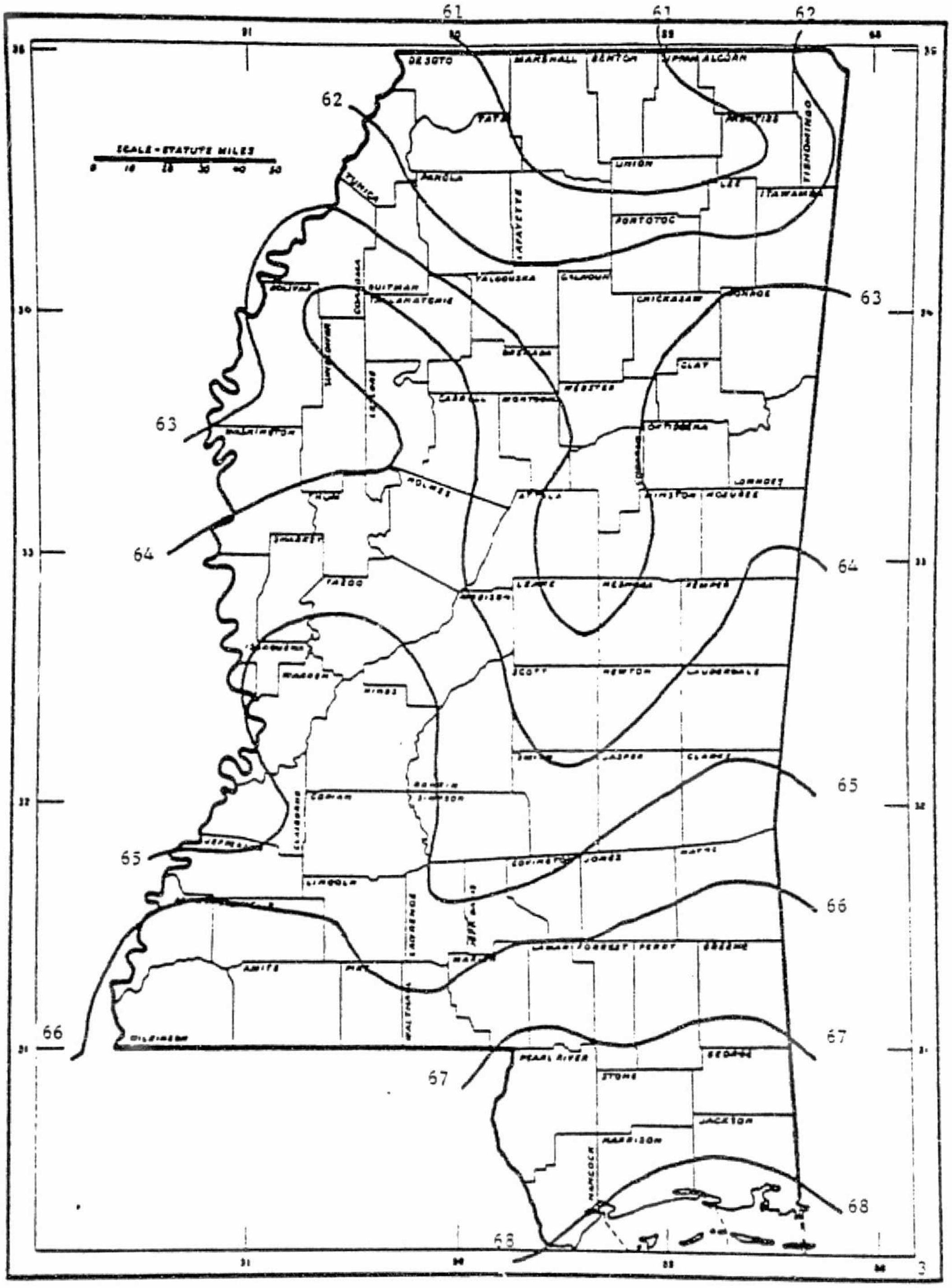

Figure 5.4 Normal Annual Temperature 1941-1970 (degrees F)

(Source: Mississippi Weather and Crop Report 1966-1975, Mississippi Crop and Livestock Reporting Service)

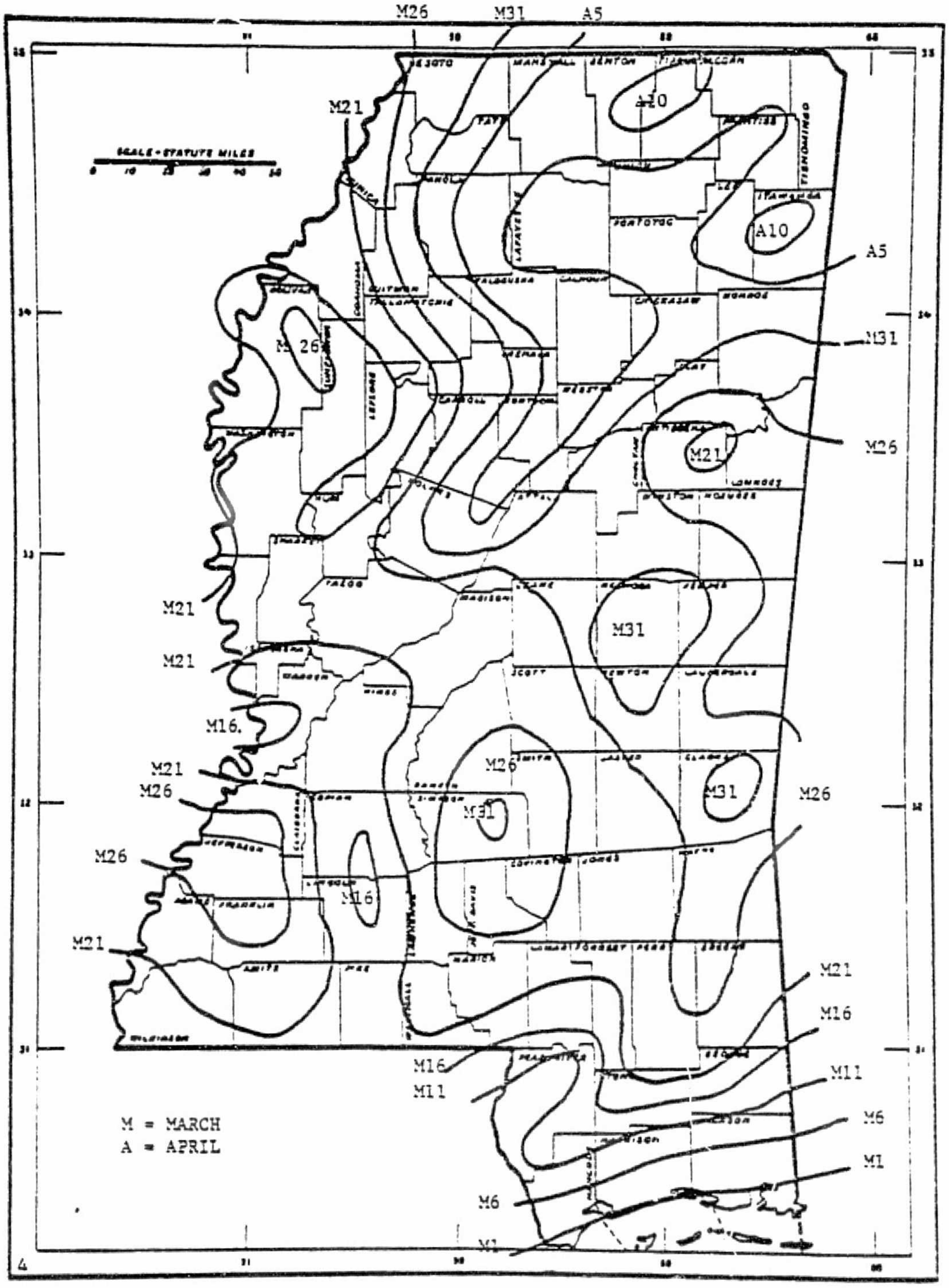

Figure 5.5 Median Date of Last Freeze in Spring (T ≤ 32°F) 1954-1973

(Source: Mississippi Weather and Crop Report 1966-1975,
Mississippi Crop and Livestock Reporting Service)

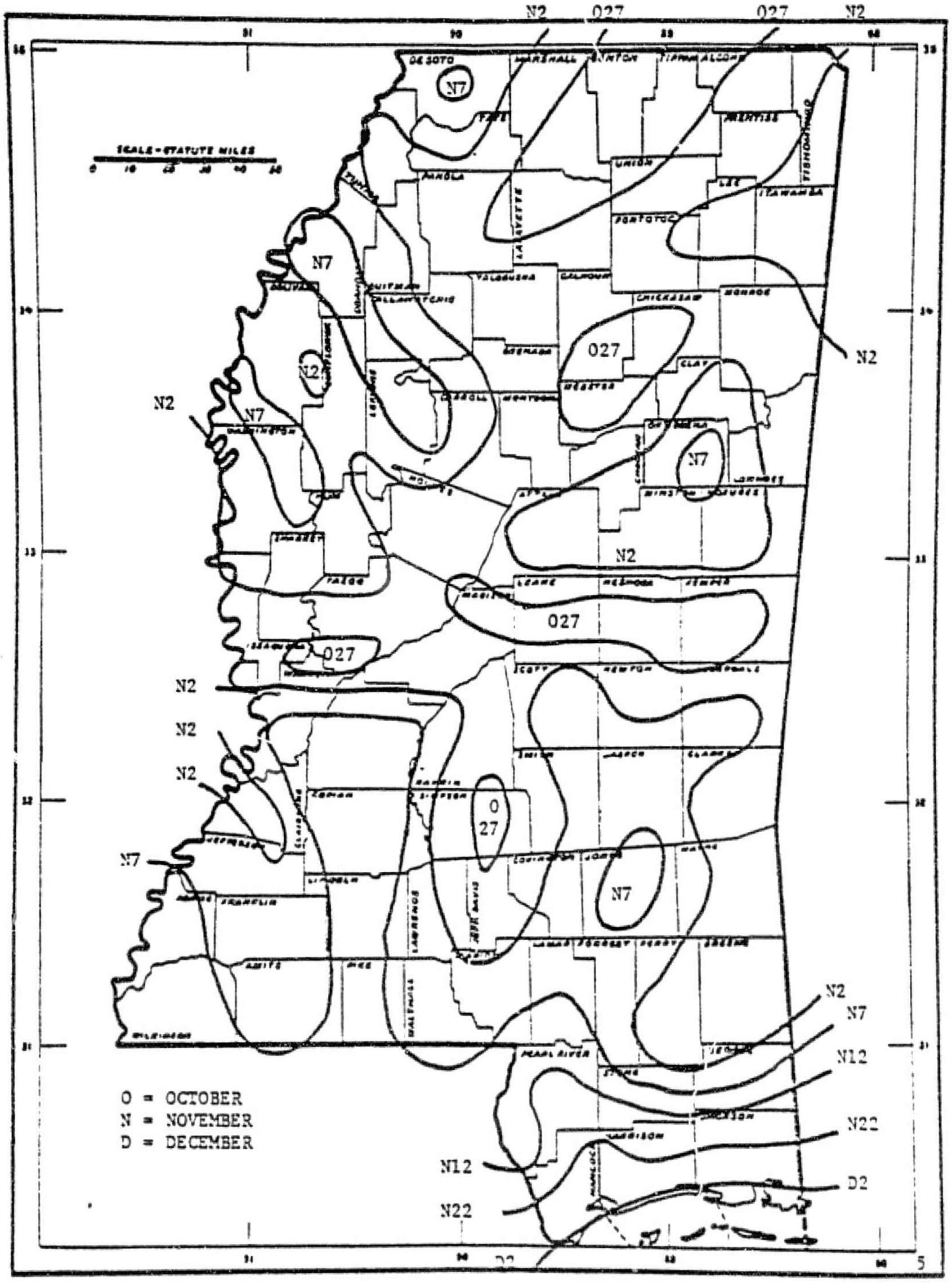

Figure 5.6 Median Date of First Freeze in Fall (T $\leq$ 32°F) 1954-1973

(Source: Mississippi Weather and Crop Report 1966-1975, Mississippi Crop and Livestock Reporting Service)

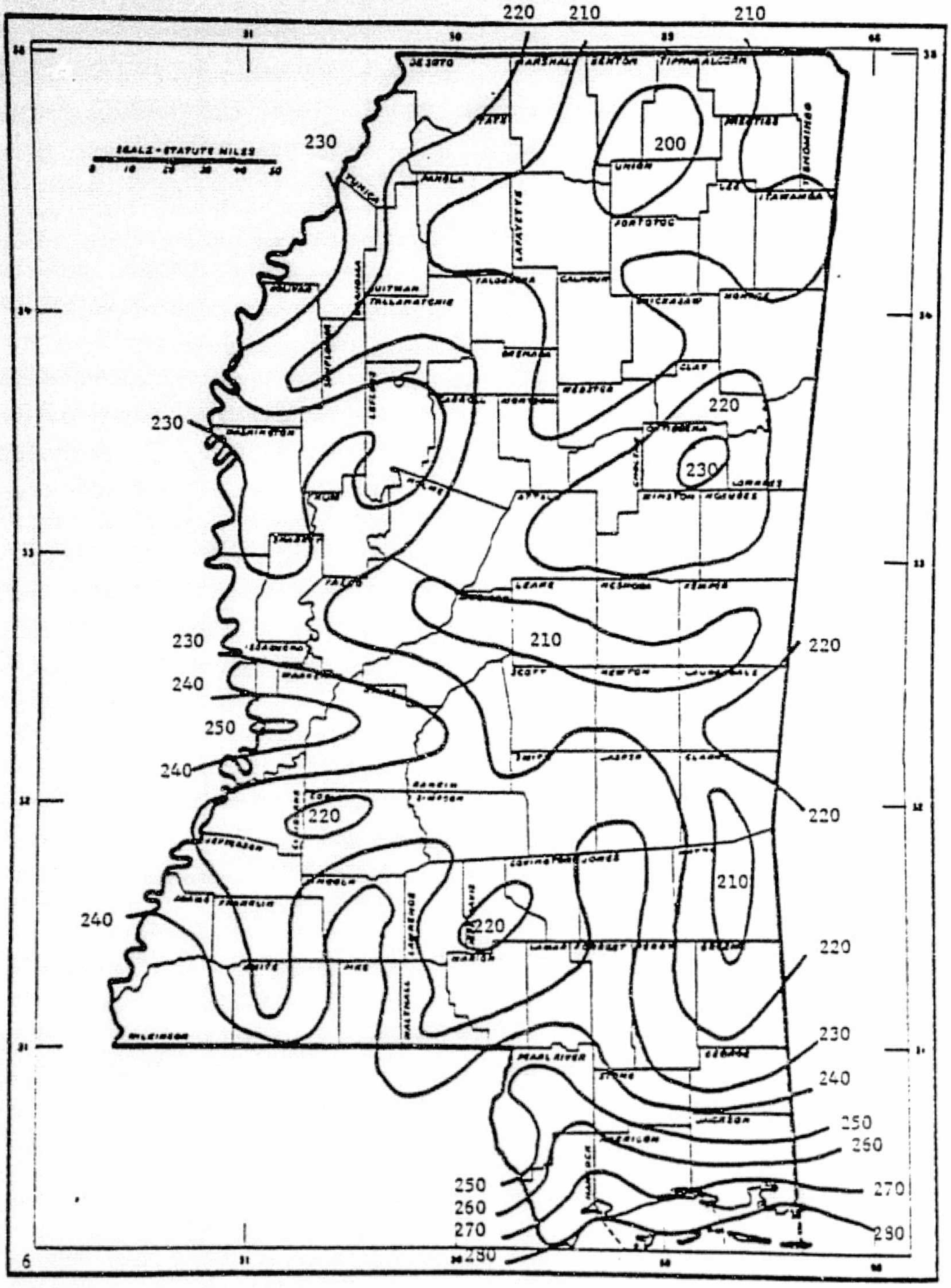

Figure 5.7 Average Length of Freeze-Free Season (Days) 1954-1973

(Source: Mississippi Weather and Crop Report 1966-1975, Mississippi Crop and Livestock Reporting Service)

when identical weather occurs throughout the area are probably extremely rare, especially during the growing season. During this time frontal activity is quite low and the weather occurrences which most frequently affect a farmer's daily decision making result from micro-climatic systems which develop in the area. Generally during the summer months humidity is quite high. A typical day might be hazy during the morning and clear off for the midday followed by a cloud build-up and thunder showers during the afternoon. These showers can vary in intensity and amount from 1/4 inch or less to 1-1/2 inch or more. These occurrences seem to be quite random and although rainfall average out quite uniformly over a several year period, individual fields may vary considerably within a single operation season (e.g., planting season, harvesting season, etc.). It should be noted that the extent of low cloud cover (haze) in the morning is normally inversely related to thunderstorms during the afternoon. For the purposes of this experiment, local variations must be adjusted by normalizing to a standard number of days for performing each specific operation. Thus the possibility of identifying benefits that in reality are merely cost savings due solely to local weather variations during a short (two to five year) experiment must be eliminated. A detailed explanation of this process is given in section 5.4.1.

5.2.1.3 Distribution of Farm Size and Production

Mississippi is made up of 82 counties, 12 of which are designated the Delta region (see Figure 5.8). Table 5.2 lists the number of farms

Table 5.2 Distribution of Farms by Size

(Source: 1969 Census of Agriculture, Department of Commerce)

County	Number of farms by class							
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Part-time	Part-retirement
ADAMS	10	13	13	13	39	41	128	65
ALCORN	11	24	47	117	180	211	424	164
AMITE	32	59	80	84	128	198	323	201
ATTALA	14	38	48	85	159	242	422	217
BENTON	17	32	53	71	99	94	222	81
BOLIVAR	179	119	74	119	198	141	127	113
CALHOUN	23	48	93	152	232	183	264	107
CARROLL	29	35	50	66	153	152	183	105
CHICKASAW	28	39	52	95	128	121	259	151
CHOCTAW	3	8	15	51	82	128	231	147
CLAIBORNE	17	12	28	49	44	64	120	74
CLARKE	6	10	26	40	72	117	245	192
CLAY	20	38	46	58	84	117	227	148
COAHOMA	156	56	49	52	89	34	60	51
COPIAH	27	40	58	103	144	181	352	257
COVINGTON	65	30	18	56	103	226	331	186
DE SOTO	58	58	47	72	122	133	312	197
FORREST	18	23	17	36	61	55	178	95
FRANKLIN	3	5	15	23	39	68	134	58
GEORGE	11	21	28	48	82	84	184	50
GREENE	18	20	15	25	50	57	154	75
GRENADA	25	29	27	51	98	94	144	73
HANCOCK	-	14	12	21	21	44	82	28
HARRISON	4	7	15	21	42	38	154	39
HINDS	39	52	86	166	297	236	496	264
HOLMES	64	40	59	81	179	289	276	237
HUMPHREYS	80	59	60	68	109	75	68	59
ISSAQUENA	42	16	13	31	18	16	22	16
ITAWAMBA	44	40	49	104	147	182	359	169
JACKSON	1	9	8	13	36	21	147	39
JASPER	26	28	35	72	145	176	367	231
JEFFERSON	9	12	29	43	63	89	146	109
JEFFERSON DAVIS	27	18	40	80	124	283	342	239
JONES	201	72	43	78	115	137	499	197
KEMPER	6	19	34	84	178	185	269	224
LAFAYETTE	18	26	40	90	154	129	340	147
LAMAR	16	6	19	38	73	93	250	100
LAUDERDALE	8	11	18	59	107	106	405	215
LAWRENCE	5	10	20	40	84	170	245	140
LEAKE	112	43	55	94	180	276	502	278
LEE	46	77	69	109	188	170	453	151
LEFLORE	137	52	46	48	56	47	41	13
LINCOLN	34	69	43	45	116	127	374	188
LOWNDES	32	45	54	83	126	181	275	172
MADISON	63	38	65	90	139	223	424	307
MARION	28	47	28	49	113	203	457	186
MARSHALL	46	43	49	101	180	306	340	246
MONROE	37	77	82	120	198	213	376	234
MONTGOMERY	18	23	38	71	119	120	208	120
NESHOBA	26	35	34	82	196	249	496	304
NEWTON	55	51	39	69	132	169	405	237
NOXUBEE	51	33	69	53	146	167	233	210
OKTIBBEHA	41	42	34	64	102	111	278	127
PANOLA	66	74	101	142	247	254	328	259
PEARL RIVER	17	34	37	48	112	93	288	70
PERRY	25	24	20	14	22	67	140	77
PIKE	22	54	44	51	62	118	271	154
PONTOTOC	26	55	79	149	246	281	523	228
PRENTISS	25	49	63	127	252	191	397	148
QUITMAN	86	74	78	67	95	80	60	45
RANKIN	120	61	49	97	122	138	315	168
SCOTT	135	62	61	113	145	174	344	200
SHARKEY	77	31	31	16	41	13	32	14
SIMPSON	154	38	41	62	138	210	370	240
SMITH	228	85	44	64	125	221	323	210
STONE	5	11	27	19	33	18	104	46
SUNFLOWER	173	107	113	114	137	64	89	45
TALLAHATCHIE	112	94	79	94	146	107	124	72
TATE	47	65	84	113	198	171	279	177
TIPPAH	23	30	71	114	220	274	467	204
TISHOMINGO	11	18	35	58	118	192	313	127
TUNICA	37	25	27	22	53	37	[illegible]	27
UNION	19	37	[illegible]	133	201	212	465	190
WALTHALL	39	32	102	99	149	296	402	233
WARREN	25	16	16	45	61	32	121	73
WASHINGTON	192	62	52	55	32	37	85	49
WAYNE	45	30	19	55	32	130	215	140
WEBSTER	8	19	52	109	121	119	236	107
WILKINSON	22	30	32	50	41	37	125	90
WINSTON	3	27	52	108	187	234	431	240
YALOBUSHA	14	24	35	53	116	142	232	164
YAZOO	94	79	78	107	174	118	244	155
MISSISSIPPI, TOTAL	3 991	3 312	3 799	5 935	10 063	11 684	21 730	12 035
Percentage of total within the Delta (underlined)	35	23	18	13	12	7		

by size and by county in Mississippi. Thirty-five percent of the Class 1* farms lie within the delta, while there is a declining percentage in each of the other classes. (These figures are from the 1969 Census of Agriculture but USDA representatives in the area indicated that the numbers of farm by size had not changed significantly.)

Table 5.3 indicates the number of acres and production of cotton by county in Mississippi. The Delta region harvested 60 percent of the acres of cotton and 65 percent of the bales produced in Mississippi. Although these figures change slightly from year-to-year, the proportion is thought to remain relatively constant. It should also be noted that much of the cotton produced outside the Delta is produced in the counties which border the Delta region.

5.2.2 Effects of Weather and Weather Forecasting on Cotton Farming

5.2.2.1 Weather Forecast Sensitive Farming Practices

The average income per acre of cotton land in the Delta is approximately \$500 (assuming a 2 bail/acre yield and cotton at 65¢/lb). The direct and fixed expenses excluding the cost of land are about \$250/acre with fixed expenses representing about 20 percent of these expenses. Fixed expenses which include the cost of equipment and interest on borrowed money are almost completely insensitive to weather and weather forecasting while both yield and direct expenses are very much influenced by seasonal weather and to a lesser degree, weather forecasting.

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*Class 1 \$40,000 or more of farm product sales
Class 2 \$20,000 to \$39,999 of farm product sales
Class 3 \$10,000 to \$19,999 of farm product sales
Class 4 \$5,000 to \$9,999 of farm product sales
Class 5 \$2,500 to \$4,999 of farm product sales
Class 6, part time or part retirement \$50 to \$2,499 of farm product sales depending on age and employment status of the operator.

Table 5.3 Distribution of Cotton Production
(Source: 1969 Census of Agriculture, Department of Commerce

County	Cotton					
	All farms			Class 1-5 farms		
	Farms reporting	Acres	Bales	Farms reporting	Acres	Bales
ADAMS	21	904	1 206	6	845	1 173
ALCORN	789	9 596	9 944	299	6 897	7 314
AMITE	180	1 045	734	34	366	275
ATTALA	479	9 483	10 069	184	7 716	8 520
BENTON	463	10 782	11 906	224	9 229	10 344
BOLIVAR	925	110 935	115 740	622	108 369	113 871
CALHOUN	663	12 552	13 589	425	11 269	12 270
CARROLL	364	10 658	12 113	205	9 966	11 231
CHICKASAW	328	10 063	8 811	172	8 848	7 808
CHOCTAW	161	1 721	1 661	66	1 267	1 226
CLAIBORNE	127	1 850	1 917	35	1 261	1 475
CLARKE	93	1 414	917	23	1 023	701
CLAY	197	3 954	3 923	67	3 364	3 466
COAHOMA	462	86 009	125 013	367	85 036	124 120
COPIAH	233	3 367	2 949	63	2 336	2 322
COVINGTON	251	4 008	2 516	67	3 008	1 883
DE SOTO	544	22 277	22 737	215	20 136	21 195
FORREST	12	66	55	2	19	13
FRANKLIN	2	87	106	1	79	101
GEORGE	11	79	63	1	36	40
GREENE	27	290	134	12	200	86
GRENADA	279	9 169	10 304	155	8 454	9 672
HANCOCK	-	-	-	-	-	-
HARRISON	-	-	-	-	-	-
HINDS	492	14 209	15 055	193	12 296	13 630
HOLMES	694	30 735	40 097	287	28 233	37 912
HUMPHREYS	466	43 698	48 427	337	42 679	47 558
ISSAQUENA	126	11 754	20 456	98	11 596	20 337
ITAWAMBA	467	6 912	6 326	212	5 345	4 963
JACKSON	-	-	-	-	-	-
JASPER	156	1 347	689	50	867	406
JEFFERSON	51	307	213	12	136	103
JEFFERSON DAVIS	302	4 533	2 441	85	3 342	1 772
JONES	138	2 497	1 305	55	1 893	918
KEMPER	376	4 033	3 218	138	2 674	2 262
LAFAYETTE	450	11 371	10 835	215	9 572	9 541
LAMAR	30	334	196	9	213	119
LAUDERDALE	116	1 473	1 109	28	1 009	643
LAWRENCE	165	1 759	1 016	35	880	504
LEAKE	642	8 670	7 829	206	6 157	5 856
LEE	593	17 107	15 189	302	15 313	13 680
LEFLORE	379	67 771	79 040	313	66 895	79 643
LINCOLN	24	611	444	5	519	392
LOWNDES	458	10 482	10 494	161	8 699	9 188
MADISON	833	26 369	23 020	274	22 850	20 497
MARION	221	2 620	1 486	47	1 459	799
MARSHALL	921	23 136	21 527	339	19 126	18 200
MONROE	719	22 167	20 958	330	19 792	19 086
MONTGOMERY	380	6 291	7 224	185	5 118	6 579
NESHOBA	345	4 412	3 602	141	3 041	2 572
NEWTON	43	490	320	18	356	240
NOXUBEE	487	8 917	7 528	158	6 993	6 110
OKTIBBEHA	115	1 318	817	41	799	550
PANOLA	857	30 349	34 292	452	27 840	31 794
PEARL RIVER	3	5	3	-	-	-
PERRY	21	352	280	11	286	241
PIKE	96	536	257	16	124	75
PONTOTOC	977	13 841	13 335	408	10 589	10 552
PRENTISS	867	13 240	13 404	410	10 363	10 876
QUITMAN	512	53 795	69 432	375	52 169	67 729
RANKIN	183	5 521	6 368	82	5 124	6 074
SCOTT	270	4 747	4 200	116	3 994	3 555
SHARKEY	182	27 155	43 234	156	26 909	42 996
*SIMPSON	265	3 167	2 052	73	1 973	1 346
SMITH	118	2 772	1 463	52	2 402	1 236
'STONE	-	-	-	-	-	-
SUNFLOWER	756	119 878	116 893	611	114 716	112 398
TALLAHATCHIE	571	57 311	72 372	425	56 791	71 743
TATE	589	20 526	23 094	371	18 469	21 265
TIPPAH	888	10 583	10 541	347	7 607	8 206
TISHOMINGO	544	5 929	5 461	183	3 881	3 636
TUNICA	237	41 931	46 900	188	41 357	46 417
UNION	756	12 335	12 796	350	9 963	10 625
WALTHALL	326	3 125	1 915	69	1 531	969
WARREN	72	5 529	8 214	42	5 343	8 256
WASHINGTON	493	79 265	113 141	352	77 754	111 932
WAYNE	91	1 334	763	34	1 014	593
WEBSTER	426	7 722	8 003	235	6 449	6 840
WILKINSON	24	737	1 129	6	679	1 097
WINSTON	520	5 743	4 597	212	4 127	3 345
YALOBUSHA	397	10 658	11 246	164	9 184	9 865
YAZOO	532	37 709	49 251	339	34 227	47 927
MISSISSIPPI, TOTAL	28 584	1 222 317	1 383 067	13 869	1 125 010	1 304 532
Percentage of total within Delta counties (underlined)		60	65			

During the planting process, which typically takes several days per field, the farmer will vary the depth at which the seeds are planted depending upon expected soil moisture. Since better seed depth placement results in better germination, the percentage of successful germination could be increased if more accurate soil moisture forecasts were available. However, in this area, forecasts for a period of time greater than 24 hours, are necessary. Because of this, the benefits resulting from improved planting time decisions (i.e., germination and the resulting yield changes) and cost reductions, attributable to the existence of the television disseminated information, are expected to be minor and so subtle as to be immeasurable during the conduct of the ASVT.

Yield reduction may also result from weed competition. However, since control is generally accomplished during the critical period (refer to Section 5.2) by ground work which is not particularly sensitive to improved forecasting, little measurable benefit from the television dissemination of information is expected. Yield reduction due to insects is more sensitive to improved forecasting because of the aerial application of pesticides. However, since many of the bolls which are damaged and drop off would have normally (without insect damage) been dropped, yield improvements directly resulting from the television dissemimation of information can not be clearly defined or measured in the process of this experiment.

Certain direct costs such as herbicides, insecticides and defoliant applications are quite heavily affected by weather forecasting while other direct costs, such as picking and cultivating costs, are insensitive to weather forecasting.

The applications of herbicides (mostly by ground equipment) and of insecticides and defoliants (mostly by airplane) amounts to approximately $50/acre. If inclement weather occurs too soon after spraying, the spraying is wasted. Costs associated with use of chemicals would decrease if better short term forecasting reduced washoff frequency. The reduction in direct costs attributable to reduced washoff of these chemicals and the reduction in the quantity of chemicals washed off are the major anticipated benefits from the television information dissemination and the only benefit which appears measurable during the conduct of the ASVT. Potential benefits occurring as a result of diminished spray washoff are discussed in Section 5.4.3. The weather conditions that result in the need to respray are described in the following section.

5.2.2.2 Weather Occurrences Requiring Respraying

Rain is the only weather condition which can completely negate the effects of herbicides, insecticides or defoliants. Temperature influences the exposure time needed for the various chemicals to work. Wind can preclude or curtail operations but will not result in losses unless airplanes are not available at a later date or drift causes damages to neighboring areas. As discussed in Section 5.4.3, there appears to be an adequate number of planes and sufficient flexibility in available spraying hours under usual weather conditions, to support farmer spraying requirements, therefore, little benefit from better wind forecasting seems likely from the planned television dissemination of information.

5.2.3 Historical Data

Generally historical farming data of the type necessary to measure the economic benefits of new information, is not available in

Mississippi. Information which is available is either rather spotty or in aggregate form. If, however, such data is found to be more extensive than anticipated once a sample of growers is selected such information could be used to in effect extend the number of years of cost and loss estimates being considered.

5.2.3.1 Availability of Historical Weather Data

Historical weather data is available from several sources for Mississippi and Arkansas. The NWS in both states collect identical data. Much of this data is compiled and sent to the National Climatic Center in Ashville. Data from all the NWSO's and the NWSFO in Jackson (and Little Rock) are compiled in Ashville. Each station includes the following data:

1. Sky conditions and ceiling,
2. Visibility,
3. Precipitation,
4. Sea level pressure,
5. Temperature,
6. Dew point,
7. Wind speed,
8. Wind direction, and
9. Altimeter setting.

In addition, Jackson supplies wet bulb temperatures and relative humidities. Of all the above, wind conditions and precipitation are the most important to spraying decisions and operations. If these conditions are unfavorable for spraying, the operation must be cancelled. If it has begun, spraying must be stopped and perhaps repeated. However,

dew point and temperature also affect the effectiveness of the chemicals and therefore affect the required drying times.

General forecasts are made only at Jackson and Little Rock. The NWS Agricultural station in Stoneville takes the early morning forecast from each of these and modifies them to be more suitable to the agricultural user and to include recommendations pertaining to activities which are likely to be performed during the day.

Verification of the forecasts takes place only for Jackson and Little Rock. This means that even though the forecast is made for the entire state only observations made at the Jackson (Little Rock) station are used for verification. The verifications indicate that Jackson and Little Rock compare quite closely in accuracy in all forecast ranges (i.e., next 12 hours, 12-18 hours, etc.)

5.2.3.2 Relevance of Available Historical Data

Historical data which is currently available, as opposed to that which might be collected for the experiment under consideration, are generally limited to aggregated data. A few farmers do keep records which would be available. Some keep weather data such as temperature maximums and minimums and precipitation. A few growers also indicated an ability to determine the number of times per season that pesticides were washed off by rain by checking for irregularities in the spraying schedule. Many of these farmers could also supply information on the material and application costs of the lost applications. These types of data are understandably somewhat less reliable then those which are gathered on a daily basis. However, these in combination with aggregated production, cost and loss data as well as historical weather data can

be used to lend confidence to the results of an experiment which in itself will likely cover only a few years.

5.3 Current Weather Forecasting Capability

5.3.1 Delta Weather Forecasting

Weather forecasts for the Delta area originate in the NWS state forecasting offices in Jackson, Little Rock, Memphis and New Orleans. Each of these offices issues zonal forecasts for each section of their respective states as shown for Mississippi in Figure 5.8, at 5 am, 11 am and 5 pm covering the next 36 hours (see Figure 5.9 for an example). Each forecast includes predicted temperature range, wind velocity, probability of precipitation and special information when relevant. Agricultural forecasts are prepared and issued at 5:30 am and 5:30 pm each day. Typical contents of such a forecast are shown in Figure 5.10. Forecasts for the period from 36 hours through 120 hours are issued once daily and are strictly based on computer forecasts.

In addition, on an hourly basis, weather condition updates are provided to wire sources for broadcast by local media (see Figure 5.11 for sample). Formal warnings for intense storms and tornados in the Delta are the responsibility of the NWS offices in New Orleans and Memphis; however, weather advisories and radar sightings of severe weather originate at the Jackson and Little Rock stations also.

Based upon the 5:00 am Delta zonal forecasts, the 5:30 am agricultural forecasts and soil temperature readings for various locations, the NWS office at Stoneville prepares specific agricultural advisories for each section of the Delta and issues them at 11:00 am to the wire services. These are most often used in preparing for the afternoon's activities. Figure 5.12 presents a sample of such an advisory.

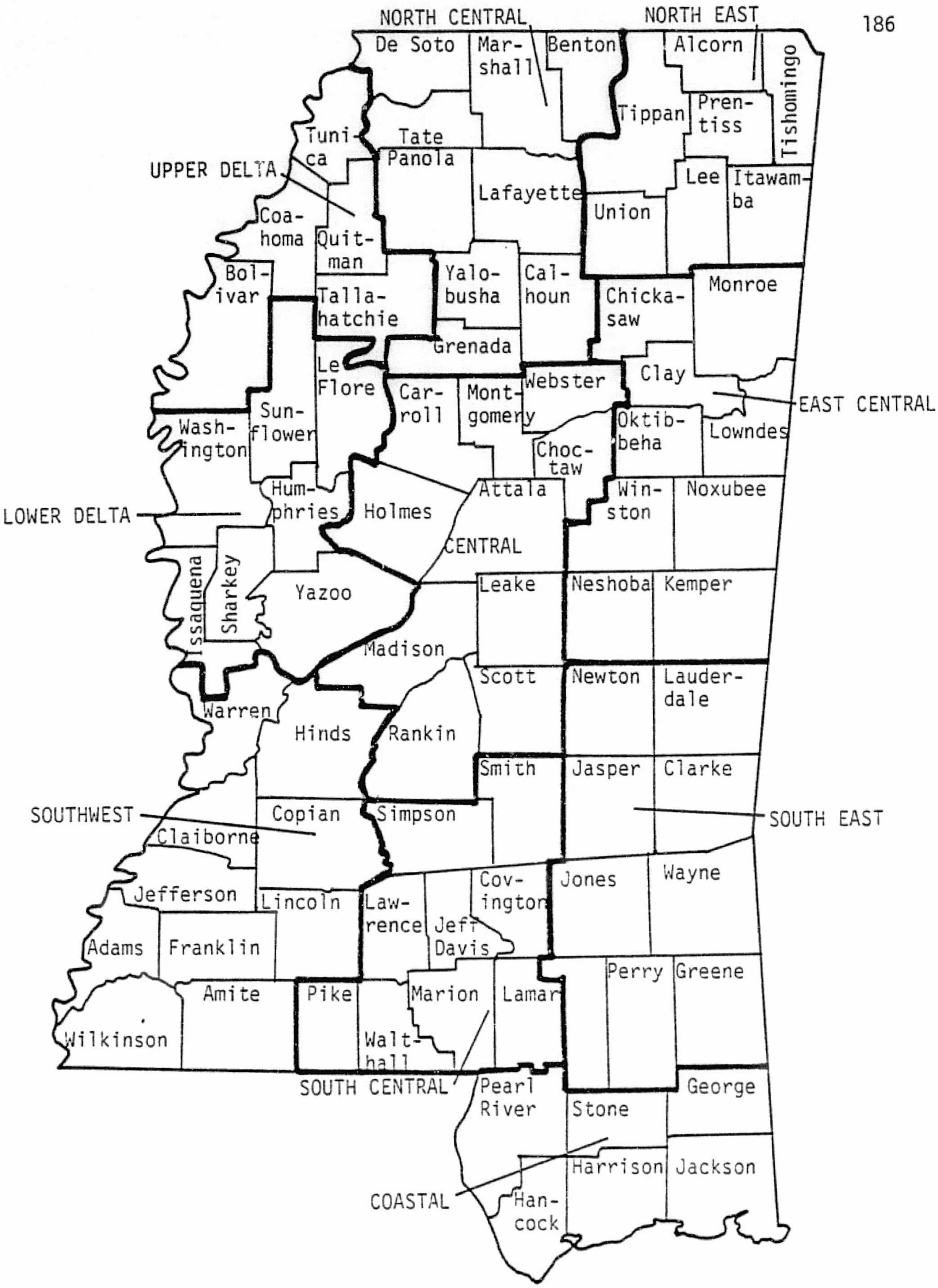

Figure 5.8 Mississippi NWS Forecasts Zones

WEST TENNESSEE

Precipitation...50 percent chance today 50 percent chance tonight and 20 percent Tuesday. Amounts one quarter to one half inch in showers.

Drying Conditions...fair today and Tuesday. Outside of showers humidities below 60 percent 10am to 6pm both days. Lowest humidity 45 percent both days.

Dew...light today drying off by 930am. Light where vegetation now wet from showers Tuesday drying off by 1030am.

Sunshine...5 hours today and 5 hours Tuesday.

Winds...southerly 10 to 15 mph today diminishing to 10 mph tonight. Northwest 10 mph Tuesday.

Outlook...partly cloudy Wednesday. Chance of showers Thursday and Friday. Highs in the 70s, lows in the 50s.

Rural Fire Danger...the Tennessee Division of Forestry advises that careless field and debris burning are high on the wildfire causes. A low Class Two fire danger is forecast for today.

MIDDLE TENNESSEE

Precipitation...30 percent probability today 50 percent tonight and 30 percent Tuesday. Amounts one quarter to one half inch in showers.

Drying Conditions...fair to poor today and Tuesday. Humidities below 60 percent 10am to 6pm both days. Lowest humidity outside of showers 50 percent both days.

Dew...moderate today drying off by 1030am. Light where vegetation not wet from showers Tuesday drying off by 1030am.

Sunshine...7 hours today and 4 hours Tuesday.

Winds...south 10 to 15 mph today. Southeast 10 mph tonight. Westerly 10 mph Tuesday.

Outlook...same as West Tennessee.

Figure 5.9 Typical 5:00 a.m. Zonal Forecasts

(Source: NWS Publication)

Arkansas Agricultural Weather Forecast
National Weather Service Little Rock AR
530 am CDT Mon May 10 1976

...North Delta...South Delta...Arkansas west of the Delta...

Precipitation...a chance of thundershowers today and tonight with precipitation amounts from 1/4 to 1/2 inch. No precipitation expected Tuesday.

Drying Conditions...fair to good today with afternoon humidities near 55 percent. Good Tuesday with humidities falling into the 40 percent range.

Dewpoints...50s and 60s today and early tonight diminishing into the 40s later tonight and Tuesday.

Dew...none this morning or Tuesday morning but leaf wetness due to rain scattered areas of the state both days.

Sunshine...3 to 6 hours today and 7 to 10 hours Tuesday.

Winds...mostly southerly increasing to greater than 7 mph after 10am CDT today and west to northwest 5 to 10 mph tonight.

Extended Outlook...Wednesday through Friday...a chance of showers Thursday and Friday. Highs in the 70s and 80s and the lows mostly in the 50s.

Figure 5.10 Typical NWS Agricultural Forecast

(Source: NWS Publication)

Weather Radar Summary
National Weather Service Little Rock AR
235 pm CDT Fri May 14 1976

At 235pm CDT...scattered light to moderate rainshowers with isolated thundershowers were indicated in western Arkansas...generally west of a line extending from 10 miles west of Clarksville to Hope.

Movement was to the north at 20 miles an hour with little change in intensity or coverage during the past hour.

Heavier thunderstorms are occurring in northeast Texas and northwest Louisiana and their present movement will bring them into Arkansas during the next hour.

Figure 5.11 Typical Hourly Weather Update

(Source: NWS Publication)

Louisiana Agricultural Weather Advisory
National Weather Service Stoneville MS
1100am CDT Mon May 10 1976

Farm Weather Outlook Thru Friday...general shower activity will be noted in LA today. Some heavy thunderstorms are being picked up on radar in east central LA. Thunderstorm activity will diminish tonight, with a dry spell expected thru mid week before showers return about Friday.

North LA...

Field Work...recurring showers today may wet down fields missing previous rains. Field work will be at a standstill in most areas. Dry soil will soak up the rains quite well, and a return to field work will be possible by Thursday in most parishes. Interruptions are due again Friday.

Herbicide Spraying...spraying operations will be hampered today in shower activity. Good spraying weather should return Tuesday and Wednesday as showers end. Wind conditions will be most favorable for a few hours after sunrise Tuesday, with winds in excess of 10 mph forecast after 10am.

Soil Temperatures...mild daytime temperatures and warmer nighttime readings will allow soil temperatures to recover to good levels for cotton seed germination and emergence Tuesday. Cooler soil temperatures are due Wednesday and Thursday, but they should not drop below an average of 69 degrees at planting depth.

Haying...showery weather today will delay any attempts at hay cutting. Tuesday, Wednesday and Thursday are expected to be rain-free, but showers are expected again Friday.

Poultry...poultrymen are advised of daytime temperatures up to 75-80 degree range and nighttime temperatures in the 50s thru Tuesday.

South LA...

Field Work...field work will be halted today in recurring showers after weekend rains brought much needed moisture. Showers are expected to end tonight to usher in a dry period until showers return about Friday. Some soybean planting will be resumed later in the week as soils dry.

Soil Temperatures...soil temperatures are expected to remain at favorable levels for good germination and seed emergence thru Friday.

Herbicide Spraying...showers will make for a poor spraying day today. Winds of 10-15 mph after 10am Tuesday will cause drift problems.

Haying...a rainless spell is expected Tuesday, Wednesday and Thursday with interruptions to haying as showers return Friday.

Figure 5.12 Typical Stoneville Agricultural Advisory (Source: NWS publication)

Another set of advisories based upon the weather updates and the afternoon agricultural forecast are prepared and issued in the evening to be used in planning the next day's activities.

These advisories are prepared with the help of USDA and Mississippi State Extension Service farming specialists. Thus, special emphasis is given to the weather parameters important to the type of activities being undertaken by farming interests at the given times of the year.

Each state NWS station formulates its zonal forecasts on the basis of climatology predictions (i.e., the results of extensive computer simulations of the atmosphere and evolving weather conditions), current weather conditions within a few hundred miles, radar imager, hourly interval satellite cloud cover pictures, hourly interval satellite enhanced infrared cloud cover pictures, and the experience and judgement of the forecaster. The forecaster on duty has the final responsibility for the forecasts and will disregard the climatology-based prediction when it is thought to be incorrect. Verification testing of precipitation forecasts done during the last few years indicates that the individual forecaster improves upon the computer predictions for the first twelve hours, is about equal during the next twelve hours, and is less accurate during the final twelve-hour period predicted during each forecast.

In the past, the forecaster has relied heavily upon currently reported conditions of temperature, wind, radar information regarding precipitation (radar is capable of detecting significant rainfall and its intensity up to 250 miles away) and experience to indicate when to

modify the computer forecast. The availability within the last several months of enhanced infrared cloud cover pictures on an hourly basis now provides the forecaster with knowledge of cloud top elevations and their rate of buildup or dissipation. This information was indicated as being of increasing value by the personnel in Jackson and Little Rock and they predicted that further experience with these pictures should permit further increases in accuracy. In neither state was much use made of the cloud cover pictures by weather forecasters. The absence of discrimination between precipitation and non-precipitation bearing clouds made it very difficult to apply cloud cover pictures [18]. The limited utility of such data is supported by the apparent absence of a theoretical framework within which to interpret the meteorological effects of clouds; this necessitates excluding such pictures from computer modeling of climate and weather.

Interestingly, an effort is made by each station to notify stations in adjacent states when it is going to contradict the computer forecast thereby permitting them to modify their forecast so as to minimize forecasting discontinuities at state borders.

Certain of the NWS offices have the capability of datafaxing their radar images to other stations having the required receiving equipment. At this time, only the New Orleans and Memphis weather stations have broadcasting capability, while all four stations have receiving capability, it is not known when the Little Rock and Jackson stations will acquire the equipment necessary to transmit their images. Until then, the radar images from the other stations would have to be used for the NOWCASTS. This could be a problem in the Southern Delta

area of Mississippi where low level precipitation could be missed by the New Orleans and Memphis weather radar since they are in excess of 150 miles away. This even is, of course, much nearer the Jackson station (less than 100 miles).

Both the Little Rock and Jackson NWS stations make use of a rotating disc synchronized with a strob-light called a "Fuggi wheel" upon which hourly radar images or enhanced infrared cloud cover pictures are placed in time sequence. By running the wheel, a motion picture effect is realized and movements in precipitation areas and cloud heights can be visualized. This technique was indicated as being particularly useful for tornado forecasting. The similarity in effect between this procedure and the "movie loop" which will comprise a portion of the information to be distributed via the television network is noted.

Weather data is collected at many locations throughout the Delta on an hourly basis and is condensed and published by the NOAA Environmental Data Service at the National Climatic Center, Asheville, North Carolina. In addition, precipitation and temperature extreme data is compiled for several stations throughout the Delta (see Reference 19). The relevancy of this data to the experiences of a particular farmer is suspect since the spotty thundershowers typical of the Delta region may result in wide discrepancies in precipitation within a few miles radius. As previously mentioned, forecast verification data is also published at Asheville but is limited to Jackson in Mississippi and Little Rock in Arkansas. Since neither location is in the Delta, some additional work would be required to determine the accuracy of the Delta zonal forecasts.

5.3.2 Weather Forecasting and the Cotton Farming Decision Process

The farmer considers the weather forecast in making his decisions regarding the planting and spraying of cotton. Planting decisions require long-lange forecasts regarding soil temperature and moisture in the soil. Spraying decisions are based upon short-range forecasts (a maximum of the next 24 hours).

Typically, the farmers seem to listen to the weather forecast on the late evening news the night before, then update it with the morning forecast and hourly observations by listening to the radio. The difficulty with the weather forecasts is that they are typically inconclusive regarding the prospect for rain in any specific location especially during the spraying season. Thus, the sprayers will augment the forecasts by calling the flight service station for current radar results and some farmers and pilots listen to a radio station to the west of their location in hopes of learning what weather to expect within the next few hours.

A new avenue of weather forecast dissemination will apparently soon open in Mississippi in the form of a continuously broadcasting weather radio station. The information to be broadcasted via this station will apparently be similar to that currently broadcast on weather stations in major metropolitan areas; i.e., hourly conditions at several dispersed weather station locations, current radar precipitation data and indicated movement of the precipitation, the current short-range and long-range weather forecasts, and notices and warnings when appropriate. The broadcasts will be at the FCC assigned weather

report frequency (i.e., approximately 162 MHz) and will require a special audio receiver. Typical short wave receivers can receive these broadcasts and it is noted that even some AM/FM clock radios on the market have a special button to push for the weather broadcasts.

This new capability is important in that it will not be available in Arkansas for at least the next year and will provide access by the Mississippi farmer to current radar precipitation information at the turning of a switch. This information would undoubtedly improve the aerial spray washoff experience if the farmer utilized the service and the weather updates were timely. Discussion with the farmers leads one to believe that they will be sure to avail themselves of the service. However, personal experiences with the New York City broadcast indicate that information is not always likely and several hours can elapse between updates. Only experience will determine the effects of the weather broadcasts in Mississippi.

5.4 Experiment Concept

5.4.1 Overview

The cotton growing ASVT is concerned with disseminating up-to-date weather information, especially including cloud cover pictures from the SMS, to cotton farmers so they can improve their short-term (12 hours or less) weather-related decision process. The weather information is to be broadcast via the Mississippi state-owned educational television network (ETV). It is anticipated that the improved weather information will materially reduce the frequency of herbicide, insecticide and defoliant washoff on cotton, thereby saving the farmers the cost of the wasted chemicals, benefiting the environment through

reduction in total application of powerful chemicals and saving fuel actually consumed in wasted spraying applications and the fuel equivalent in the petrochemicals not applied.

Figure 5.13 delineates the information and guidance interfaces envisioned for the economic experiment portion of the NOWCAST demonstration. As indicated, the coordinated efforts of members of the NWS, MAFES, USDA agricultural personnel and Colorado State University (CSU) participants will define, establish and produce weather programs for hourly broadcast on the Mississippi state educational television network. The coverage of the state network is shown on Figure 5.14. It should be noted that Mississippi is completely blanketed by the television coverage indicating that information distributed by the network will automatically be available to cotton farmers throughout the state.

The contents of the NOWCAST programming currently envisioned by Colorado State University are shown in Table 5.4. As indicated in the table, the 6:00 a.m. and noon programs will be expanded to include specific agricultural advisory information and all shows will provide up-to-date cloud cover pictures from the SMS with radar precipitation imagery superimposed to indicate the rain producing clouds. The dialogue accompanying the pictures will provide interpretation of the current NWS forecast and explain the implications of the latest weather observations. The equipment necessary to receive the cloud cover pictures and radar imagery and to provide the cloud cover loop will be provided by NASA.

Using the pictures in conjunction with the discussion presented on the broadcast, it is anticipated that the individual farmers

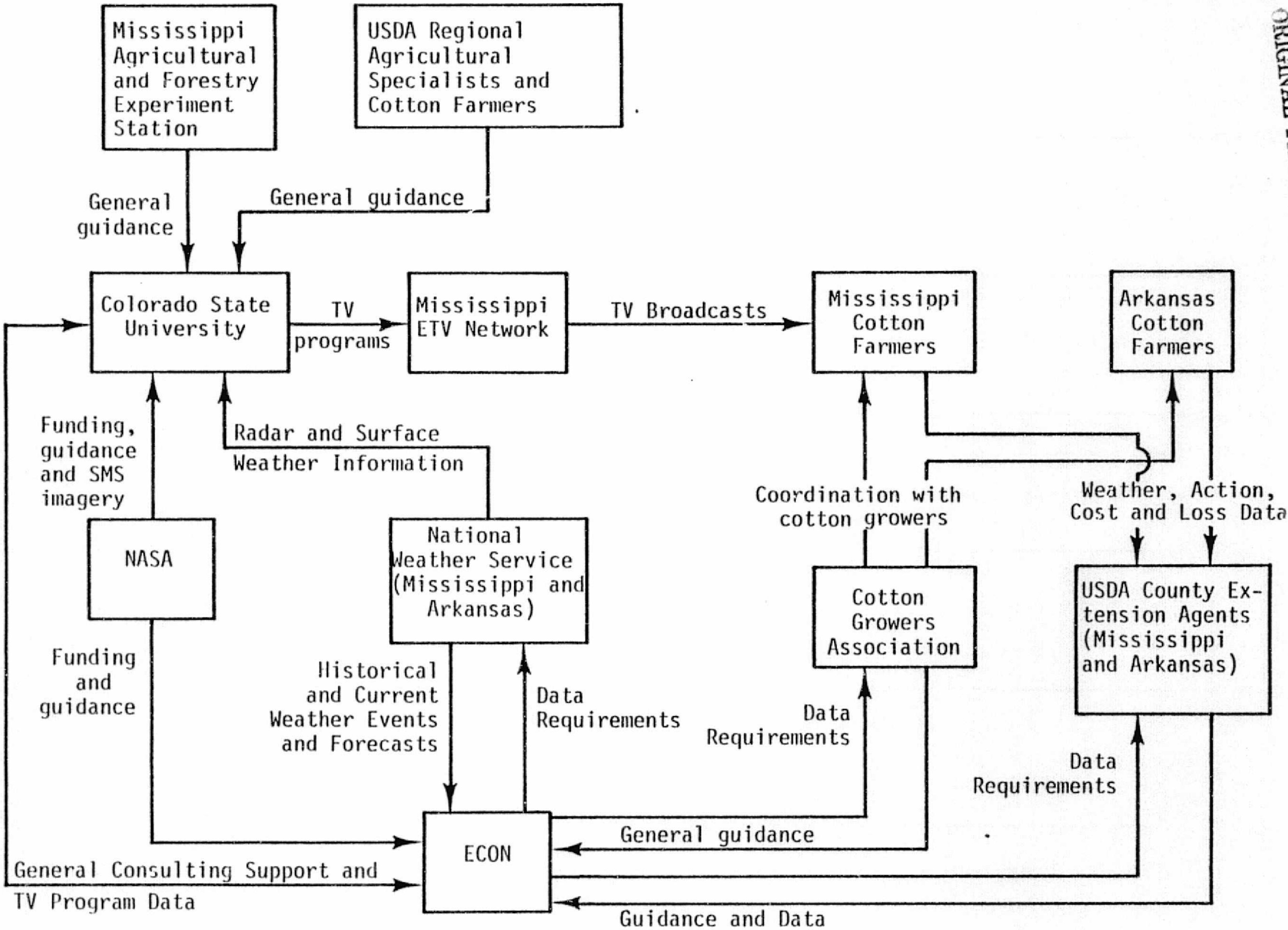

Figure 5.13 Participants in the Mississippi ASVT

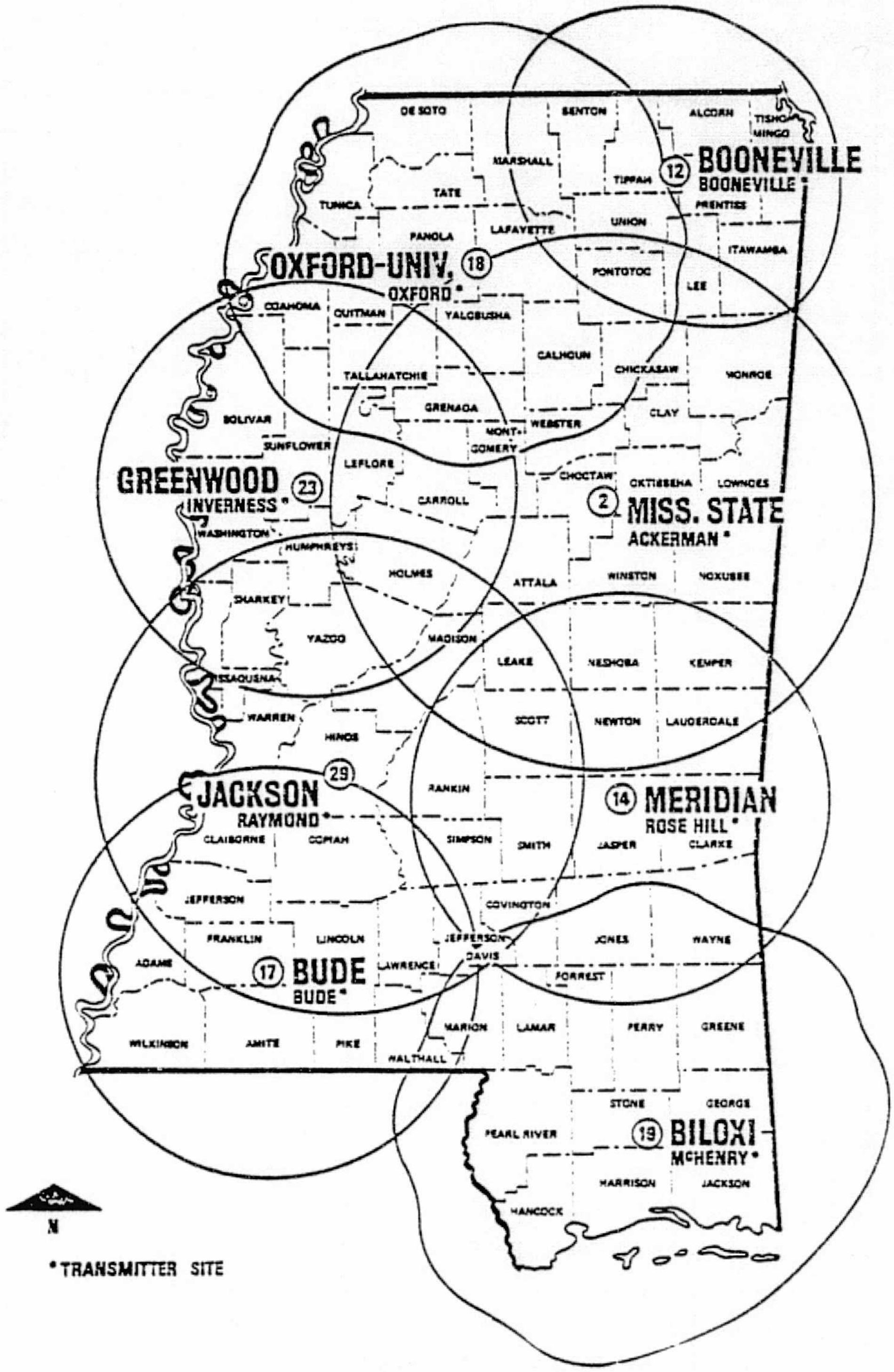

Figure 5.14 Mississippi ETV Stations
(Source: Mississippi Authority for Educational Television Publication)

Table 5.4 Typical Daily NOWCAST Program Format

4 Minute Program (Hourly 0600-1600)

Picture

1. U.S. Cloud Cover (SMS)
2. Movie Loop 36 Hour U.S. Cloud Cover (SMS)
3. Local Area Cloud Cover (SMS) (Radar)
4. Surface Weather Map
5. Special Weather Map
6. Special Weather Map
7. Special Weather Map
8. Special Weather Map
9. Special Weather Map
10. Special Weather Map
11. U.S. Cloud Cover (SMS)
12. Movie Loop 36 Hour U.S. Cloud Cover (SMS)
13. Local Area Cloud Cover (SMS) (Radar)

Audio Interpretation

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10 Minute Program (6:00 am and Noon)

Same as 4 minute program, but additional advisory information (crop, growing degree days, soil moisture)

will be able to see their particular area and localize and update the NWS forecast so as to better foresee precipitation occurrences up to the next 12 to 24 hours. Based on this improved information, it is anticipated that the farmer will be able to make more accurate decisions regarding the timing of chemical applications. The principal anticipated benefits from the improved knowledge will be the savings in the cost of wasted chemicals and application costs, and reduction of chemicals washed off due to unforeseen rain.

To measure the benefits which may result from the dissemination and use of the new information, a sampling program for data collection must be undertaken which relies upon the farming practices, soil types and meteorology in the Delta. Based upon a later judgment as to the desired level of accuracy, a group of farmers and their alternates will be selected on the basis of farm size, farming practices and locale. Although no obvious distinctions in practices have been identified based upon farm size, there may well be some subtle differences in risk aversion or success of the entierprise which may well correlate with farm size, making it prudent to ensure a sample weighted by size. Farmers will be selected on a county basis to assure more even sampling and greater likelihood of accurate sampling relative to insect "hot spot" infestations. The sample farmers will be asked to record, among other things on a daily basis, weather forecasts, weather occurrences, whether or not spraying was indicated and the type of spraying, the acres sprayed (if any) and the cost per acre. If spraying was done, then the farmer would indicate the rationale for

the spraying both from meteorological and horticultural viewpoints and a judgment as to the efficacy of the spraying.

The sample population selection should place heavy emphasis upon the experiences of USDA County Extension Agents and from the MAFES and USDA regional agricultural specialists who have done random sampling in the Delta in the past. Based upon discussions with some farmers, it appears that there is a general willingness to endure some extra paper work as long as it appears that a potential payoff exists for them in the form of improved weather forecasts.

It is anticipated that the data collection can be performed approximately weekly by the USDA County Extension Agents and sent to ECON for data reduction and interpretation. Since spraying, at least from the ground, commences shortly after planting, and defoliant spraying extends into the fall, the data will need to be collected and compiled for almost the entire growing season from early May into September.

Since it seems likely that the farmers will require a familiarization period before they will be able to fully utilize the information disseminated via TV, it is considered necessary that the test period cover a minimum of two growing seasons. Due to equipment availability constraints, it is assumed that the first year of the test cannot begin any earlier than the 1978 growing season.

The ASVT economic experiment will not be able to separately define the benefits from the SMS cloud cover pictures being made available to the individual farmers; rather, it will measure the total effect from all the new information and its hourly dissemination on

farming practices. With regard to measuring the effects of normal weather forecasting and media dissemination, the option exists of using the Mississippi cotton farmers during the growing season of 1977 (also 1978 if NOWCAST begins in 1979) or using Arkansas cotton farmers concurrently with the Mississippi test group during the 1978 and following growing seasons. Current indications are that insufficient records exist upon which to establish a control group based upon farming experiences of previous years. It is, however, necessary to establish a control group to obtain the detailed data against which the test group will be compared. Based upon the assumed timing of the availability of information and other considerations, it is recommended that the control group be run concurrently with the test group. The test group will be in Mississippi and the control group in Arkansas. It should be noted that the Mississippi farmers can also serve as the control group if the timing of the ASVT will support data gathering during the 1977 growing season.

It is anticipated that weather conditions, spraying requirements and weather forecasting accuracy will vary significantly between the test and control gropus. Since it is desired to measure the economic benefits associated with the television distribution of SMS and other realted data, these variations need to be eliminated before accurate estimates of the NOWCAST benefits can be made. To do this, a methodology has been developed which has the effect of normalizing the control group results so that they correspond to that experienced by the test group <u>except</u> for the presence of the NOWCAST broadcasts. As explained in Section 5.4.2, the normalization process will require

use of weather forecasting data which will be obtained from the NWS data center in Asheville, North Carolina. The details of the normalization process are given in Appendix B.

The Mississippi cotton ASVT differs materially in concept from the Florida citrus ASVT in three major areas. The first difference is concerned with the forecasting capability. In the Florida test, improved forecasting by the NWS is anticipated to result from the use of the University of Florida computer program together with SMS input data, whereas in the Mississippi test, information currently utilized by the NWS in forecasting the weather, viz, hourly SMS cloud cover pictures and continuous radar surveillance will be reformatted and televised to the farmer over ETV in the hope that the information recipient will be able to modify his weather zone's short-term NWS forecasts to better anticipate the occurrence or nonoccurrence of precipitation on his particular set of fields.

The second major area of difference is associated with the potential benefits arising from the test. In Florida, it is anticipated that the processed satellite data will permit reduction in frost-related losses (i.e., yield improvement) as well as savings in frost protection costs. In Mississippi, the experiment will concentrate on measuring the monetary benefits accruing from savings in the purchase of chemicals and their application and will not attempt to measure yield modification effects. This situation arises because expected yield improvement due to improved short-term forecasting is anticipated to be small (but finite) for reasons described in Section 5.4.3, and will be impossible to measure in a several-year experiment

due to the large seasonal yield variations experienced in cotton farming in the Delta.

The final major difference has to do with the potential availability of a control group outside of Mississippi that could permit simultaneous collection of test and control group data. This is possible because cotton farmers in Arkansas west of the Mississippi River will not be able to receive the NOWCAST programming but do have similar soil and cotton cultivation practices. Thus, the Arkansas farmers could be used to supply the control group data necessary to ascertain the benefits which result from the television dissemination of information on spraying costs. Three possibilities exist for forming the control group, namely (a) to use cotton farmers in Mississippi during the growing season prior to the initiation of the television broadcasts, (b) to use cotton farmers in Arkansas concurrently with the Mississippi test group, and (c) a combination of both (a) and (b). The last alternative, (c), is obviously the most desirable from the point of view of experiment design. It, however, along with the first alternative, (a), requires data collection to precede the television dissemination of information by one year and may cause scheduling problems. The outlined experiment plan is based upon establishing a control group in Arkansas concurrently with the Mississippi test group (b). This approach, though not the most desirable, provides flexibility as to approval and implementation timing.

5.4.2 Methodology

To measure the benefits associated with the television dissemination of information to the cotton farmers in the Mississippi

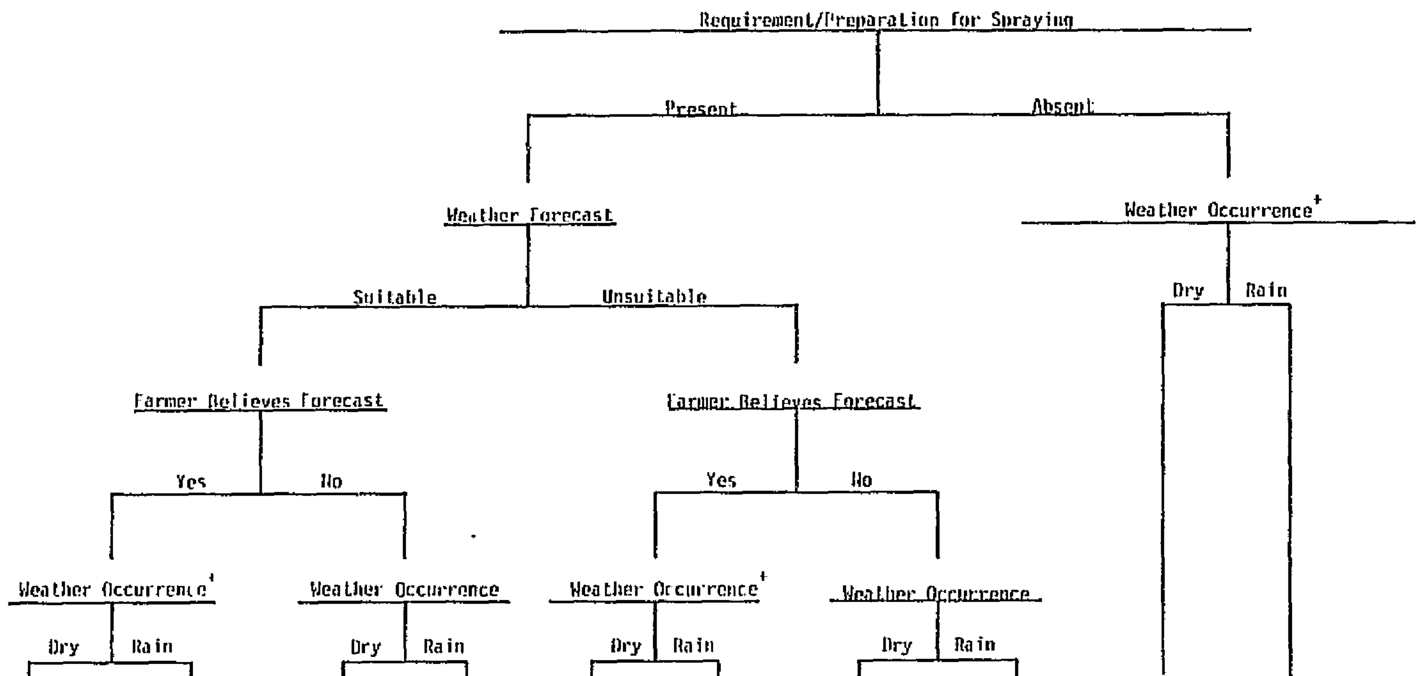
River Delta section of the State of Mississippi, care must be taken to properly account for the seasonal variations in rainfall patterns and the varying amounts of chemical spraying done in any one season depending upon weather, weed and insect conditions. Otherwise, the extrapolations from the sample data to the entire farming acreage will be fallacious and the comparison between control and test group results inaccurate. In addition, it would be valuable for the methodology to reflect different degrees of farmer risk averseness and if the control group is to be from a different locale than the test groups, the methodology should reflect differences in forecast quality and weather patterns as they relate to the farmer's ability to anticipate his own weather.

The methodology described in this section attempts to consider variable weather factors and spraying frequency and to indirectly include risk averseness as it is related to management decisions made by farmers with different size farms. It is assumed that NWS weather forecast quality and the scrutability of weather patterns as they relate to farming decisions are the same for both control and test groups. This assumption seems eminently reasonable if a Mississippi control group is used but, perhaps, less so if an Arkansas control group is used. The methodology presented in Appendix B explicitly considers differences in NWS forecast quality and will be utilized if found to be necessary.

For reasons discussed in Sections 5.4.3 and 5.4.4 it is proposed to measure only the benefits associated with the reduced washoff costs of chemicals and their applications during the conduct of the ASVT. The chemicals to be considered and their mode of application

are as follows: post emergence herbicide application by ground equipment, post emergency herbicide application by air, insecticide application by air and defoliant application by air. It should be noted that it will not be possible to collect data on the total costs and normalize them for the average growing season in the manner proposed in the Florida ASVT methodology (Section 4.3.2). This is true because the amount of spraying required is a function of the insect infestation rate rather than directly dependent upon the number of rainy days per season; while in citrus production the amount of frost protection is directly dependent on the weather event. It will be assumed that the fraction of total cost for a particular spraying activity that is viewed as wasted will be proportional to the number of days of precipitation during the growing season period to which the spraying is appropriate.

Figure 5.15 illustrates the information that will be gathered from each cotton farmer comprising the sample during each day of the growing season for each spraying activity during its appropriate time period. The weather forecast is construed as applying to the time period relevant to spraying efficacy (typically 4-8 hours) while the rainfall refers to the total received each day in an amount greater than, perhaps, 1/4 inch (the amount typically thought of as needed to wash off insecticide). Thus, rain could occur on the day of spraying but come prior to spraying or sufficiently afterwards to permit a fully successful chemical application. Thus $0 < W_2 < C_2$ and $0 < W_8 < C_8$ depending on the judgment of the farmer as to the degree of washoff experienced. (W is the wasted cost due to washoff and C is the cost of application.)



Action:	Spraying Successful	Spraying Unsuccessful	No Spraying	No Spraying	No Spraying	No Spraying	Spraying Successful	Spraying Unsuccessful	No Spraying	No Spraying
Result:	1	2	3	4	5	6	7	8	9	10
Number of Days Out Of N^S:	NO_1^S	NO_2^S	NO_3^S	NO_4^S	NO_5^S	NO_6^S	NO_7^S	NO_8^S	NO_9^S	NO_{10}^S
Cost:	C_1^S	C_2^S	0	0	0	0	C_7^S	C_8^S	0	0
Loss:	0	*	*	*	*	*	0	*	0	0
Wasted Cost:	0_1	W_2^S	0	0	0	0	0	W_8^S	0	0

* Possible Weather Forecast Related Yield Effects Not Measurable in ASVT

† Precipitation During 24-Hour Period of Greater Than an Amount to be Determined

Figure 5.15 Event Descriptions

The following superscripting and subscripting notation is used:

s (superscript) = spraying type

i (subscript) = event type

j (subscript) = farm size designation

k (subscript) = farmer designation

d (subscript) = day

"s" is the spraying type designation as previously described. "i" is the event type as described in Figure 5.15 where $1 \leq i \leq 10$. The farm size designator, "j", refers to the intent to stratify the sample by farm size in hopes of isolating risk aversity and farming practice variations that correlate with farm size. (Tentatively a breakdown of 400-800 acres, 800-1600 acres and greater than 1600 acres appears to be reasonable.) The farmer designator, "k", refers uniquely to a particular sample point in group j. "d" is any one day during the spraying season for spraying type s.

Let $COST^s_{i,j,k,d}$ be the daily cost associated with the application of chemicals applied to a farm and $WASTE^s_{i,j,k,d}$ the daily cost associated with the application of chemicals that was wasted due to inclement weather subsequent to spraying. The total annual cost of applied chemicals and the total cost of spraying that was wasted are given by

$$TCOST^s_{j,k} = \sum_{i=1}^{8} \sum_{d=1}^{N^s} COST^s_{i,j,k,d}$$

$$TWASTE^s_{j,k} = \sum_{i=1}^{8} \sum_{d=1}^{N^s} WASTE^s_{i,j,k,d}$$

where N^S is the duration of the spraying season for spray type "s". Note that the start of the spraying season for each spray type may be different. Now let

$$SWF^S_{j,k} = TWASTE^S_{j,k}/TCOST^S_{j,k}$$

be the fractional cost of chemicals during a particular season that would be eliminated if perfect short term weather forecasting were present at the individual farm level.* To adjust this value to the normal year (recalling the assumption that the waste fraction is independent of seasonal variation in spraying frequency but proportional to the fraction of rainy days during the spraying season) normalization must be performed for the average rainy day fraction for each farmer. During the spraying period N^S for spray type s, the farmer experienced a rainy day fraction, $RDF^S_{j,k}$, given by

$$RDF^S_{j,k} = \frac{1}{N^S} \sum_{i=1}^{5} NO^S_{2i,\ j,\ k}$$

where $NO^S_{i,j,k}$ is the number of days of occurrence of event i as observed by the k^{th} farmer of size range j when using the s spray type. It is anticipated that an adjustment will be necessary to account for differences in forecasting capability and weather patterns as detailed in Appendix B. Using historical data for a weather station near each

*Note that this is an approximation since TCOST includes costs which are the result of inclement weather. For example, respraying because of washoff of spray introduces additional costs and may alter the overall spraying patterns. These effects must be taken into account when computing SWF. This will be accomplished during the detailed experiment design (see Section 5.5.2.1).

farmer or less desirable but simpler using a more centrally located NWS station, an average rainy day fraction, ($\overline{RDF}^s_{j,k}$), can be determined. The respraying waste fraction, $ASWF^s_{j,k}$, experienced by farmer k of farming group j while doing s type spraying can now be defined as

$$ASWF^s_{j,k} = SWF^s_{j,k} * \overline{RDF}^s_{j,k}/RDF^s_{j,k} .$$

In general, it is expected that the localized adjustment factors will vary from farm to farm from less than to greater than one during any one season due to the spotty rainfall patterns of thundershowers.

Now letting $ACRE_{j,k}$ equal the number of acres farmed by farmer k in group j the average fractional waste for farmers of a particular size range is determined as:

$$\overline{ASWF}^s_j = \frac{\sum_{k=1}^{MAXK_j} ASWF^s_{j,k} * ACRE_{j,k}}{\sum_{k=1}^{MAXK_j} ACRE_{j,k}}$$

where $MAXK_j$ is the number of farmers in group j.

It is necessary to determine the seasonal cost associated with spraying of each type. The variation in cost is not particularly sensitive to washoffs since washoff is estimated to occur about 15 percent of the time while, for example, the number of insecticide applications can vary by a factor of two. But rainfall is one of the independent variables which in some complicated fashion affects insect and weed growth and thereby affects spraying requirements. For the Mississippi cotton ASVT, it is proposed to attempt to rely on a several year average seasonal cost per acre for each spraying type based

on the data utilized to formulate Reference 21. If that information is inadequate, use can be made of the test group results to project the savings during particular years with the attendent level of uncertainty associated with the limited size of the test group.

The total spraying cost per acre, $\overline{TSCA}_j^s$, of cotton farm land of group j derived either as an average from historical data or computed for a particular year from test group data is given by

$$\overline{TSCA}_j^s = \frac{\sum_{k=1}^{MAXK} TCOST_{j,k}^s * ACRE_{j,k}}{\sum_{k=1}^{MAXK} ACRE_{j,k}}$$

The total cost associated with spraying operations which result in sprays which are washed away, TWSC, is given by

$$TWSC = ACRET * \sum_{j=1}^{MAXJ} \sum_{s=1}^{MAXS} \overline{ASWF}_j^s * \overline{TSCA}_j^s * FACRE_j$$

where ACRET is total number of cotton acres in the Mississippi Delta, $FACRE_j$ is the fraction of acreage which is found in farm size range j, MAXJ is the number of farm size designations or farm groups considered, and MAXS is the number of different spray types considered.

The total cost associated with spraying operations* which result in sprays which are washed away can be established for both the

*Note that these costs consider only miss statistics (i.e., favorable weather anticipated but in reality inclement weather develops). Costs associated with false alarms (i.e., inclement weather anticipated but in reality favorable weather develops) are not considered since they can only be measured in terms of yield variations.

control and test groups. If TWSC is the annual cost associated with the test group and TWSC' is the same cost but associated with the control group, the difference between the costs, namely

$$\overline{AB} = TWSC' - TWSC$$

is the average annual incremental benefits which result from the television distribution of the SMS cloud cover imagery and related data.

5.4.3 Loss Determination

Consistent with terminology used throughout this report, loss refers to the reduction in income resulting from reduced crop quality and/or quantity (i.e., yield) that could be affected by the television information dissemination. Loss effects are of paramount importance in considering cotton farming benefits since a small improvement in average yield has great financial significance. As described in the previous sections, the expected yearly income in the Delta is approximately $500 per acre of cotton land; thus, if a yield improvement of as little as 1 to 10 percent were attributable to the television distribution of information a dollar benefit of between $7.5 and $75 million would result. However, it appears that little expected yield improvement would accrue from even perfect knowledge of the weather 24 hours in advance and that what small yield increases might occur would not be measurable during the conduct of the ASVT. This situation arises due to the wide variations in seasonal cotton yield, the nature of the cotton plant and the nature of competing weeds and insect pests, and the assumed limited duration of the experiment.

The cotton seed needs 7-10 days of warm soil temperatures to germinate and approximately 180 consecutive frost-free days to achieve full boll maturity. When the cotton plant blooms, it puts on blooms equivalent to approximately 25 bales per acre and a good harvest is considered 2+ bales per acre with the record yield for a field being about 5 bales per acre in the Delta. The bloom must be pollinated during the first day after it opens which occurs 90 $\pm$ 10 days subsequent to planting. If rain occurs prior to noon on the first day of blooming the blossom will fall. Thus, if very accurate seasonal forecasts were present that would permit better timing of planting, greater fertilization and improved yield would undoubtedly occur. However, the television information dissemination cannot influence the timing decision significantly and one must look at the agricultural practices between the period of planting and harvest to see any potential yield effects. Activities during this period consist of various sprayings and cultivation (i.e., plowing the row bottoms to discourage weed growth). Cultivation is done whenever the fields are sufficiently dry and is insensitive to weather forecasting. Spraying is, on the other hand, quite weather and weather forecast sensitive, and in order to understand the conclusion that little expected yield improvement is anticipated due to the television information dissemination each type of spraying and the factors influencing its application must be considered. It should be noted that defoliant spraying which is the first harvesting step is excluded since it has no effect on yield.

Table 5.5 presents a summary of the various spraying activities that occur at different times during the cotton farming season, the problem being treated and the implications of failure to perform the spraying operation in a timely manner.

Due to a preplanting herbicide application for grasses and/or a preemergency application during planting for broadleaf weeds (these herbicides are placed two or more inches beneath the row and are therefore unaffected by precipitation) weeds are held at bay while the cotton is sprouting. Once sprouting occurs and while the plant is still young, the cotton may be bothered by thrips which suck plant juices while attached to the underside of the leaves. This pest is reasonably well controlled by systemic insecticides laid down during planting or sprayed on the plants after germination. Not all farmers spray for thrip depending on the level of infestation. If the infestation becomes heavy with numerous leaves on each plant involved then stunting plant growth with associated postponement of maturation will result. Since the thrip can weaken the plants, if cold damp weather is experienced along with the thrip*, the plant is some instances can acquire a fatal disease. Clearly, plant death would result in yield diminishment while any delay in maturing will have a probability of reducing yield depending upon when the first frost comes relative to the time of planting. However, currently little or no actual yield diminishment is attributed to the presence of thrip because of the fact that damage occurs so gradually that there exists ample time to apply the insecticide during the spring when rain occurs on the average of less than

*Not likely since the thrip do better in drier warmer weather.

Table 5.5 NOWCAST Influenced Spraying Operations [22-25]

Cotton Development Stage	Spray Type	Number and mode of Application*	Spraying Objective	Timing Considerations	Worse Case Failure Effect
Seedling	Larvicide (3-6 hours)	Aerial (1)	Control of Thrip and infrequently cutworms	Timing not critical; infestations will appear gradually and continues to be controllable	Heavy infestation will retard rate of plant development and given cold, damp weather could cause fatal plant disease
Prior to and including squaring stage	Herbicide (1-6 hours)	By ground equipment in bands under cotton (2-4)	Keep T-weed and other plants down beneath cotton	Timing not critical; preemergence herbicide will depress weed growth while cotton sprouting but larger weeds more resistant to chemicals	Weeds grow larger than cotton necessitating hand weeding or "over the top" herbicide application and retarded cotton development
	Herbicide (MSMA) (4-8 hours)	Aerial or high boy ground (≤ 1)	Knock down weeds grown larger than cotton and not retard cotton growth unduly.	Done only when control of weeds lost	Reduced yield due to cotton shading and competition for soil nutrients, and reduced cotton quality due to weed material present during harvest
Bloom to open bolls	Ovicide/larvicide combination (3-12 hours)	Aerial (≈ 10)	85 percent control of tobacco bud worm and boll worm	Timing critical; insects must be controlled during 8-10 day period following laying of eggs, first generation quite discrete	Destruction of crop if insects not controlled prior to time of large larval development
			Incidental control of boll weevil	No damage if controlled within 5 days of adult emergence	Some crop yield diminishment; reduction in "wintering over" cover has cut breeding population below economic treatment level except for that incidental to bud/boll worm treatment

one in three days. The likelihood of having yield measurably affected seems very remote with or without MOWCAST.

Prior to the blooming stage, the cotton plant is sufficiently small to experience competition from grasses like Johnson grass and broadleaf weeds like T-weed (a cousin to cotton). To stifle the weeds, herbicides are applied while fields are cultivated. The weeds remain susceptible to the herbicides throughout their life but require less herbicide when they are small. Also, if they remain shorter than the cotton, band sprayers can direct the herbicide underneath to cotton leaves, thereby permitting larger doses to be applied to the weeds without harming the cotton. The exposure of cotton to herbicides is a currently debated topic with some experts claiming that the typical post emergence applications of herbicides do more to stifle yield than do the weeds being treated by the herbicides.

The herbicides are applied from the ground and if the ground stays too wet for egress for a period of a week or more (possible from one very heavy thunderstorm) the weeds may achieve a height comparable to or greater than the height of the cottom. In such a situation, the farmer can no longer control the weeds through band spraying and must rely* on overhead spraying, typically done by airplanes in Mississippi. The spray used, MSMA, will kill most of the weeds but will also result on some retardation in cotton maturation. In addition, limited hand

*It should be noted that the farmer must restrict the weed growth to protect from yield reduction arising from severe competition for nutrients and shading of the cotton by the weeds. In addition, the existence of weeds in the picked cotton will lower the cotton grade although special defoliants which are successful in dessicating weed leaves can be used to reduce this problem.

weeding is done in selected locations to remove particularly stubborn specimens.

Clearly, if a MSMA application is required there will be a probabilistically determined reduction in yeild do to delayed boll formation with attendant greater frost exposure risk. However, the successful application of herbicides is not particularly sensitive to the weather forecast. By and large, the farmers cultivate the beds and spray the herbicides any time the fields are sufficiently ory (average is about 3-5 days/week suitable for field work in the spring) [26]. Even if caught by a surprise rainfall, the acres covered by wasted spray will only be in the range of 12 to 80 acres depending upon the herbicides applied, the number of ground sprayers being used and the stage of cotton development.

In summary, the television dissemination of information could be credited with a yield improvement from its use in herbicide application to the extent that it would help farmers avoid the expected yield reduction from use of MSMA. However, the only situation where this could occur would require the farmer to have foregone ground spraying when the land was sufficiently dry due to an erroneous expectation of imminent precipitation, and then to have subsequently received so much rainfall as to preclude timely spraying. Since the most land affected would be 12-80 acres and in view of the extremely unlikely weather factors that would have to occur, it appears that little yield improvement seems potentially accruable from the television dissemination of cloud cover related information. Of course, the new information will be completely ineffective regarding yield improvement to the extent

that farmers continue to spray as long as soil bearing strength permits regardless of their beliefs regarding imminent precipitation, (indicated as being standard operating procedure in some areas).

The typical cotton plant will pollinate and set around 4 to 5 times as many bolls as the plant in its Delta environment can accommodate. The surplus bolls will eventually fall from the plant unless previously eaten by insects.

Only the boll eating insects are an economic (i.e., treatment is cost effective) summer time problem. The principal insect pest, the insecticide resistant tobacco bud worm, and the more traditional pest, the boll worm (the boll weevil is no longer an economic pest) become serious problems from about late July until September. In fact, in 1975 significant yield reductions were attributed to infestations of the bud worm which were not diagnosed until the insects had attained a size where they could not be efficiently killed or controlled even with special insecticides.

To understand the reason that these worms reach a stage where they are no longer treatable, their life cycle must be examined. For either worm, a generation takes approximately 30-35 days with 1-3 days as eggs laid in the terminal (i.e., top) leaves of a suitable plant, 15 days as a larva that slowly works its way down the plant to eat on the buds and bolls, and 15 days as a pupa before metamorphosis to adulthood is completed. When the adult moth emerges it mates and is almost immediately ready to lay eggs. The damage to crops occurs during the larval stage. The newly hatched worm will eat small squares and leaf terminals near the top of the plant. From about the

fifth day on, the worm will drift slowly down the plant and begin feeding on the larger squares and eventually bolls. If uncontrolled, these worms have the capability to strip cotton plants of all fruit and then, traveling from one adjoining limb to another do the same to contiguous plants. They will not travel across the ground to get from one plant to another.

The standard method for dealing with these worms is to spray by air (at least in Mississippi) a combination of methyl parathion and an ovicide. The methyl parathion kills recently hatched and exposed worms (say up to 7 days old) and is active about 4 hours (2 hours half life under normal conditions) while the ovicide kills eggs in from 6 to 12 hours depending upon weather conditions. A very successful spraying is considered to be one that kills more than 90 percent of the eggs and worms. Once the worm reaches 7 days in age, they require not only much more "methyl" for a "kill" but more importantly are down lower in the plant, typically in bolls, where their chances of coming into contact with the larvicide is quite low. Spraying is indicated when eggs and/or worms are detected on 6 percent of the cotton plants (rule assumes 50 percent reliability of worm detection). A typical year will see 4 to 5 generations of the worms.

Since no amount of spraying will keep all worms from reaching adulthood and laying eggs, it is necessary to spray frequently during the summer months especially after the one generation per year beneficial insections (e.g., wasps) has been killed by the first methyl parathion application.

If insect spray is washed off due to an unanticipated rain during the early season when the surplus bolls have yet to fall, no yield will occur. To quote Reference 23, "vigorously growing cotton (i.e., cotton during its first 5 weeks of squaring when it is increasing its square population by 2 1/2 fold weekly) can withstand fairly heavy infestations without yield loss". This happens not only because of the available surplus bolls but also because the worm population is reduced by beneficial insect predation. However, later in the season a situation could be experienced where "as the squaring rate declines and the boll load increases, lighter infestations are more likely to cause economic boll damage" [23]. Thus, in late summer if a farmer should let a generation of worms get to the 5 to 7 days stage without being controlled, he will experience a very severe yield reduction.

Early in the year the generations are relatively discrete and a combination of moth traps (indicating egg laying moth swarms) and scouting reports normally inform the farmer of the impending need to spray. Later in the season the generation becomes much less discrete and spraying must be done on a schedule which will ensure that every insect has been exposed to poison by the time it is 5 days old.

As previously indicated, it is possible for a farmer to find himself severely damaged by worms in late season. However, this situation is unlikely to occur if proper diagnosis of infestations is done due to the economic and rainfall patterns; viz, the insecticide costs even for more expensive late season insecticides like lannate*

*Lannate cannot be used earlier in season due to its deliterious effects on yield.

are still less than \$5 per acre, and the average probability of rainfall on a given day of more than a quarter of an inch is no greater than 30 percent. The expected crop yield when compared with the expected cost of spraying strongly motivates the farmer to continue spraying until a kill occurs. In spite of this it is possible, though unlikely, that a stretch of bad weather (say five consecutive rainy days) in the late summer coupled with bad luck or inattentiveness in spraying timing would result in diminished yield.

Looking at the possible effect that improved 12 to 24 hour forecasting could have, it must be recalled that the rainfall typically occurs in short duration thunderstorms that may be worked around if accurately predicted. Thus, it appears likely that improved forecasting will diminish the number of applications required; however, expected yield improvement benefits must rest upon the likelihood of yield diminishment without the forecasts <u>and</u> significantly improved spraying success due to the television information dissemination. Looking first at the probability of significant yield reduction per insect generation (P_y),

$$P_y = P(A_n) \prod_{d=1}^{n} P_j(B/A)$$

where $P(A_n)$ is the probability of an amount of rainfall sufficient to wash away the insecticides for n days consecutively and P(B/A) is the probability that given rain occurs on day d it will occur with the timing necessary to wash off insecticide applied earlier that day. Assuming that the farmer might try spraying up to four times and that

six hours is needed for control, a yield diminishment probability is obtained which is on the order of:

$$P_y = 1/3\ (1/2)^3\ (1/2)^4 = .003$$

where it is assumed that weather patterns in Mississippi repeat themselves approximately 50 percent of the time and that a farmer has an even choice of spraying sufficiently early or late to avoid wash off from a rain on the same day. If complete yield elimination is assumed, then the expected loss per year, E_ℓ, is

$$E_\ell = \$500\ (4)\ P_y = \$6.00/\text{acre}$$

where \$500 is the income/acre and there are assumed to be 4 generations of insects per year.

Considering the limited case, if the information disseminated via television could insure that a window for successful spraying is alwasy found then the maximum yield benefit would be \$6.00/acre. However, the afternoon pattern of the rainfall indicates that early morning spray could improve the success of spraying and by using an estimate of wash off of 1/3 which more closely coincides with one farmer's estimate of 15 percent gives E_ℓ = \$1.00/acre. Since the new information available to the farmer is unlikely to permit the farmer to make flawless 6 hour forecasts every time, it is likely that the expected benefit will be less than \$1.00/acre. Furthermore, since it is anticipated that any expected yield improvement would be small and it is not possible to say with certainty that the existence and use of the new information in a specific set of circumstances resulted

in a specific yield improvement, it is necessary to rely on statistical inferences to establish possible yield improvements. During the period 1970 to 1974 the average yield harvested in Mississippi varied from .93 bales/acre in 1974 to 1.37 bales/acre in 1970 [27]. This represents a variation of nearly 50 percent and is reflective of the different weather patterns and insect infestations that can be experienced while cotton farming. Thus, the wide yearly variations in yield would necessitate a sampling size and test duration longer than anything being considered for the cotton ASVT in order to show yield effects.

It should be noted that if insecticides were in short supply or the farmer had exhausted his financial resources the yield improvement likelihood might increase above that calculated above. However, current indications are that insecticides will remain available and that a farmer who has already put $200 into his crop will find a way to add another 5 or 10 percent. Thus, an expected yield benefit of much less than a dollar per acre seems very likely.

5.4.4 Cost Determination

Cost determination refers to the expenditures which might be impacted by the television dissemination of information excluding yield effects. For reasons previously described, it is anticipated that significant potential savings in cotton farming can only arise by reducing the number of wasted spraying of herbicides, insecticides and defoliants. Benefits would accrue to the farmer to the extent that he would be saving money on wasted chemicals and the cost of their application. Possible benefits would arise in aerial spraying

to other farmers in the form of more available airplanes. Benefits to society in general would accrue from reduced release of chemicals into the ecosystem, from the reduction of speed of insect resistance buildup, and the saving in fuel and fuel equivalent hydrocarbons utilized to produce the various sprays.

The saving in fuel resulting from reduced wash off frequency, possibly on the order of 15 percent [28], is easily computed and is negligible. The other societal benefits are not readily computed and may not be significant, but are certainly real. The benefit in increased plane availability seems to be negligible due to the schedule flexibility of the sprayers and their willingness to fly in almost any weather. Their flexibility in scheduling appears to permit response within a day or two to most requests for spraying. However, accommodating those requests may necessitate spraying late in the day or the evening when showers are more numerous, thus indirectly leading to a greater exposure to risk of wash off. However, benefits to be derived from greater flexibility in time of day that spraying is done will be noted in reducing wash off frequency and need not be tied to plane availability.

The primary cost saving to the farmer is measurable and, in fact, is the only benefit which it seems feasible to measure in the Mississippi cotton ASVT. The potential magnitude of the benefits can be estimated by considering the impact of perfect twelve hour forecasting made available throughout the 1.5 million Delta acres of Mississippi cotton. The benefits may be estimated as follows:

Insecticide: 1.5×10^6 acres x .15 x \$32/acre = $\$7.2 \times 10^6$

Herbicide: 1.5×10^6 acres x .15 x \$20/acre x 1/3* = $\$1.5 \times 10^6$

Defoliant: 1.5×10^6 acres x .15 x \$ 5/acre x 1/5* = $\$\ .2 \times 10^6$

TOTAL = $\$9 \times 10^6$

where the farmer generated estimates of 15 percent frequency of wash-off was used [28]. The cost of chemicals and the exposed acres were derived from Reference 29. The estimated benefits are for the Mississippi Delta region only and will be larger when other cotton farming areas are considered.

5.4.5 Sampling Considerations

There exist many thousands of cotton farms within the Mississippi Delta and it would be a formidable and costly exercise to try and collect data from each farmer in order to arrive at an estimate of the benefits from the television distribution of information even if they were all cooperative. Thus, sampling is mandated and it is critically necessary to define the important factors that need to be considered in determining the sample population in order to arrive at an unbiased estimate of benefits that minimizes sampling variances within the economic constraints of the experiment budget (see Section 3 and Appendix A). In the remainder of this section, the parameters which importantly influence the sample selection criteria are discussed as well as certain qualitative considerations regarding the human element of the experiment. Section 5.4.6 and 5.4.7 discuss specific considerations as they relate to test group identification in Mississippi and control group selection.

5.4.5.1 Key Sampling Parameters

The important features along which the sample populations need to be stratified are the following:

1. Weather forecasting district,
2. Geographic sub-districts,
3. Farm size, and
4. Farm insecticide spraying procedure.

It does not now appear necessary to sample based upon the basic soil type, other farming practice variations or some direct measure of risk averseness.

As described in the methodology summary in Section 5.4.2, if it is necessary to use the methodology outlined in Appendix B, then the weather forecasting miss and false alarm rates will be important parameters that will be used to normalize the anticipated variation between weather and weather forecasts experienced by the various members of the test and control groups. Fortunately, this is not a severe constraint since the lowest level of forecasting resolution, the zonal forecast, is much coarser than is needed for other reasons. For example, as shown in Figure 5.8, two zones encompass the entire Mississippi Delta within Mississippi.

A finer resolution, perhaps on a county basis, will be needed in order to derive benefits estimate. One of the basic outputs from applying the methodology to the data will be an estimate of the average number of times per year that a Delta cotton acre needs to be sprayed. Based upon this estimate and other data outputs the

benefits from television disseminated information are to be computed. However, the number of spray applications of insecticides will vary significantly on a geographic basis. It has been observed that some areas of pocket infestation will need to be sprayed a dozen or more times during a particular season while other areas may require only four applications. It is also conceivable that a strain of insects significantly more resistant to the available poisons may appear initially in a limited geographic area. These variations appear to be unpredictable as to frequency or location so it appears necessary to guard against such variations by geographically stratified sampling. Since it is anticipated that data gathering will be done through USDA County Extension Agents, stratifying the sampling on a county basis may be a practical approach. Conveniently, each zone for which a forecast is prepared is composed of several counties and its borders coincide with county lines.

As previously reported for Mississippi, and also true in Arkansas, the large majority of Delta cotton acreage is found in farms of greater than or equal to 400-500 acres. Farms with more than 500 acres are typically worked in 500 acre increments. This procedure is due to the economics of scale that occur in five hundred acre cotton field multiples in the Delta. Since the benefits to be measured by the economic experiment are a direct function of total acres, it is justified to ignore the small but more numerous farms with less than approximately 400 acres.

It does not seem prudent to equate all farms with more than 400 acres. The smaller farms are typically owner run while the largest may be corporate entities with subdivided managerial responsibilities. Intermediate sized farms of 800-1,600 acres may represent the more successful individual farmers or smaller corporate entities. In addition, certain of the larger farmers own interests in aerial applicator businesses or could conceivably own airplanes strictly for their own spraying requirements although economic usage* dictates using one airplane for every 7,000-10,000 acres [28]. These differences in ownerships by farm size may also extend to financial arrangements and possibly insect scouting capabilities. All of the above considerations may modify the risk averseness of the individual decision maker and alter the go-no go decision regarding spraying in the face of less than certain meteorological conditions. As implied in the above discussion, it is our preliminary judgment that dividing the farms into three size ranges (i.e., 400-800 acres, 800-1,600 acres and more than 1,600 acres) will stratify the sample in a manner suitable for the needs of the ASVT economic experiment.

In general, cotton farming practices important to measuring the economic benefits (i.e., spraying) are standardized in approach (namely, ground application of herbicides and aerial application of insecticides and defoliants) and unpredictably variable as to frequency. However, as mentioned elsewhere, insecticides are applied

*Planes used for spraying cannot be easily modified for other uses.

with a ground spraying rig by many Arkansas, Delta farmers whenever the bearing strength of the ground permits. As discussed in Section 5.4.6, these farmers may have a different set of decision criteria and do not appear suitable for the control group. Little if any ground spraying of insecticide is indicated in Mississippi. Any farmers who do so should be excluded from the sample groups.

Soil types in the Delta run from sandy loam to hard clay and most farms of any size have areas of each soil type and fields with mixtures of both. Soil moisture considerations dictate that cotton be grown on the sandier soils and soybeans on the heavier clay soils. Thus, by restricting the economic experiment to cotton farming a de facto sample stratification by soil type occurs and differences within the cotton growing soils appear so minimal as to be negligible.

5.4.5.2 Behavioral Uncertainties

From discussions with various people knowledgeable in the ways of cotton farming it is clear that the decision criteria regarding spraying are not so definitive as to result in identical action by different farmers faced with similar situations. Unsurprisingly, the degree of risk averseness and diligence also varies significantly. This appears to be a manifestation of distributional properties for which the explanatory variables are not known. Thus a technique cannot be devised that will ensure an unbiased sampling for the relevant distributions. This limitation certainly applies to the degree of risk averseness present in decision making. It is anticipated that

stratification by farm size may well provide sufficient correlation to adequately allow for this uncertainty.

A significant practical uncertainty has to do with the need to find cooperative farmers. This will necessitate randomly selecting a preferred farmer group and then randomly selecting additional farmers to act as a fill-in group for those primary farmers who refuse to cooperate. Only experience will determine the level of farmer cooperation but if it is not high (experience to date is favorable) then there will be an uncertainty as to whether the sample as it is finally constituted is biased. Perhaps, those farmers willing to fill out the data forms will be more inclined to closely review all the available information including the NOWCAST information before making a spraying decision. Fortunately, the current impression is that a large number of farmers will be willing to keep the necessary records. Most are sound businessman and are hungry for all the weather information to which they have reasonable access. It appears that the Arkansas control group farmers will also be cooperative even though they will not initially receive the information distributed via the Mississippi television. The reason for their expected cooperativeness is that they anticipate benefits to accrue to them in the long run from the experiment.

5.4.6 Test Group Data Requirements

5.4.6.1 Test Group Meteorological Data Collection

Consistent with the methodology described in Section 5.4.2 for each member of the test group, it will be necessary to record on a daily basis the weather forecast and the weather that occurs. Since

the forecasts are issued on a zone by zone basis, they can be gotten from the NWS and recorded for both Delta zones daily. Thus, the farmer will not need to record his forecast.

The weather occurrence of interest is the weather actually experienced by each test farmer. The weather experienced at some weather bureau station, even if in the farmer's zone, is likely to be significantly different due to the widely differing precipitation patterns associated with thunderstorm activity during any one season. Each farmer will be required to keep a rain gauge record daily and each will, therefore, experience a different weather forecast accuracy rate. From personal observations, it should not be particulary difficult to get farmers to maintain rain gauge records. Several farmers that were interviewed already have installed rain gauges and one kept daily records [28, 30].

5.4.6.2 Test Group Economic Data Collection

The economic data required of each test group farmer is the cost of spraying, the reason for spraying or not spraying and his judgment as to spraying effectiveness. It appears likely, as discussed in other sections of this report, that records of the type currently kept by farmers will not be adequate for use in the economic experiment. However, it also seems likely that the data upon which the summary records currently available are based are easily disaggregated in a "real time" situation and that the farmer will have no difficulty in estimating the per acre costs of chemicals and their application. Farmers and farm extension personnel think in per acre terms and many farmers seem to know to the penny the cost of each spraying of chemicals.

It also seems "straightforward" for the farmers to record on a daily basis whether or not spraying was needed and if spraying occurred, its effectiveness in an ordinal sense. Both meteorological and economic data would be recorded on the same sheet and then collected on a weekly or biweekly basis. It appears cheapest and most efficient for the data sheets to be collected by a USDA County Extension Agent in each county. However, if that cannot be arranged, there exists the option of providing prestamped mailers that the farmer could seal and mail periodically. The exact method of collection will be determined in the next phase of the study.

5.4.7 Control Group Possibilities

From a theoretical viewpoint, there exist three possible control group opportunities that could be used in the economic experiment. These are, (a) records of Mississippi farmers prior to 1977, (b) a special data collection program in Mississippi from 1977 until the NOWCAST begins, and (c) using data from analogous farmers of the west side of the Mississippi River during the test data collection period. The methodology requires specific information that is not available in the normal records kept by even the most conscientious farmer. Thus, in reality, one must select between a Mississippi control group from which data must be collected between now and the time of NOWCAST initiation or an analogous group of farmers without NOWCAST information from whom data could be collected simultaneously with the test group. Either approach has its difficulties and its attractive

features and it appears too early to make a definite selection between them. However, for the sake of current planning the third alternative (a control group in Arkansas) is considered.

5.4.7.1 Mississippi State Control Group Considerations

Table 5.6 presents a list of the major advantages and disadvantages associated with selection of Mississippi farmers for the control group. The comparison points disaggregate into technical and managerial issues. It seems clear that the organizational structure established for the control group would be equally applicable to the test program thereby creating a practically significant cost saving vis a vis parallel data collection. Unfortunately, prudence would seem to dictate a two year period of data collection to smooth out the "wrinkles" and guarantee that a sufficient control group data bank is established.

Clearly, using Mississippi farmers would eliminate any issues associated with farm organization and horticultural practices that might differ on the east and west sides of the Mississippi River. Of course, a revolutionary change in farming practices might antiquate the control group data, although it seems unlikely that a revolutionary practice would appear that would be adopted by all Delta farmers "en mass". More likely would be the appearance of a new insect strain that would require a year or two to spread throughout the Delta.

From a purely weather data comparison perspective using Mississippi farmers would ensure that the benefits were determined

Table 5.6 Comparison of Mississippi vs. Arkansas as Possible Control Groups

State	Principal Advantages	Principal Disadvantages
Mississippi	Knowledge and organizational structure directly transferable to test group data collection Standarized farming procedures especially relative to absence of ground insecticide application NOWCAST benefits measured against Mississippi NWS forecast quality including radio weather broadcasts	Necessitates data collection in 1977 growing season Farming practices may be modified during collection period (e.g., new insecticide)
Arkansas	Delay data collection until installation of NOWCAST equipment Any farming practice modifications likely to be equally represented Site scouting program provide "natural" data collection technique	Parallel organizational structures with attendant increase in costs Existence of unbiased aerial insecticide spraying control group not certain Possible absence of radio weather and probable difference in farmer perceived forecast reliability will add uncertainty If NOWCAST is really valuable farmers near the river may get data from NOWCAST

against the continuous radio weather broadcasts thus providing a measure of the effectiveness of verbal description of radar images as compared to visual radar and cloud cover information.

In addition, the more sophisticated methodology referenced in Section 5.4.2 and Appendix B assumes that the fraction of the time the user believes favorable and unfavorable forecasts is proportional to the historical forecasting miss and false alarm rate. By restricting the control group to the same forecasting region, the need for defining the precise functional form is obviated and it can be assumed that the farmer's general consideration of the forecast reliability will not change significantly.

5.4.7.2 Non-Mississippi Control Group Considerations

Both southeastern Arkansas and northeastern Louisiana have similar climates, soils and cotton farming practices and are not slated to have NOWCAST broadcasts. Therefore, they afford the opportunity to select the control group from beyond the Mississippi boundary and collect control group data parallel to that of the test group. In general, it is considered probable that quite similar farming practices exist in both Arkansas and Louisiana. However, no detailed information is currently available on Louisiana so this discussion is restricted to Arkansas.

Table 5.6 provides a listing of the major advantages and disadvantages associated with using Arkansas. The singularly important organizations benefit is the ability to delay data collection till the spring of 1978 (assuming television dissemination starting early in 1978). This is balanced somewhat by the requirement of setting up a data collection system parallel to that utilized in

Mississippi. It should be noted that the Arkansas state scouting program may provide a simpler method of data collection and farmer interface as compared to Mississippi.

From a farming practices perspective, in Arkansas it is necessary to compensate for the smaller average farm size and disparate insecticide spraying techniques compared to Mississippi. However, the risk is somewhat alleviated of encountering some radical new condition that would modify cotton farming in general.

Radio weather broadcasts are not currently planned for Arkansas and would not be established any earlier than 1978 [31]. Thus, by using Arkansas as the control area the benefits of the television information dissemination to Mississippi farmers relative to the Mississippi state radio weather broadcasts may not be accurately established.

As can be seen in Figure 5.14 the broadcasting coverage of the Mississippi state ETV network extends slightly across the Mississippi River. If these patterns reflect a signal strength reduction of 50 percent (i.e., 3 db down) then undoubtedly farmers in Arkansas beyond the area shown in the figure will be able to receive some coverage although it may be fuzzy. Unfortunately for the economic experiment portion of the ASVT, the farmers who might receive it are the Arkansas cotton farmers in the Delta. If the television information turns out to provide truly valuable information, it seems likely that some Arkansas farmers would find a way to utilize the information. If this should happen, the entire experiment would be invalidated since it might result in no <u>measured</u> benefits while the converse were really true.

5.5 Experiment Plan

In general the following sections describe a plan for an experiment designed to demonstrate the economic benefits of the television dissemination of Synchonous Meteorological Satellite (SMS) cloud cover pictures through the NOWCAST system plus other related information to the agricultural sector in Mississippi. As discussed earlier, it is expected that cotton farmers will use this information to improve decisions on weather sensitive activities. The plan describes a technique for measuring the benefits derived from the television dissemination methods and information and as such should not be confused with a demonstration of total SMS benefits in the same context. The plan includes a description of the experiment and outlines further steps to be taken in order to set up such an experiment. These tasks include a detailed experiment design, data collection, data analysis and reporting. In addition a schedule for detailed planning and actual performance of the experiment is presented. Also, the necessary participants and their expected roles are explained and budgetary and manpower requirements are estimated.

5.5.1 Description of the Experiment

Since the experiment is designed to quantify the benefits of the television information dissemination system and since these benefits are expected to be most dramatic and measureable in the area of chemical spray applications, primary plans are concerned with these areas. The plan has been created to measure the reduction in materials and time brought about by the ability to more accurately determine the likelihood of certain weather occurances within the near future. It is

thought that this will involve primarily reduced loss of sprays (and their application costs and effectiveness) due to unexpected rain occurances shortly after application.

SMS and related information distributed via television broadcasts may also have some impact on increasing yields through more accurate timing of chemical use and other management decisions but since it is felt that these effects can not be suitably measured in the experimental time frame, they will not be included in the experimental design.

The experiment will consist of a comparison of the pesticide cost and loss measurements made for two groups of farmers. One in the Delta area of Mississippi where television broadcasts are received and the other in the Delta area of Arkansas where the ETV programs are not received. The similarities between the weather, soil types and farming practices in Mississippi and Arkansas create an unusual opportunity for establishing a control group to be measured during the experimental years rather than having to rely on time-series data and the technology problems inherent in that type of experiment. However, in view of the fact that this television broadcasting will probably not be operational in Mississippi until 1978, it would be possible to collect data from the same farmers who will be in the test group later, during the 1977 growing season and to use that data as an additional control area. While this would be added insurance against biases which might exist and are not already obvious, it would also involve additional expense. This needs to be considered more carefully during the task of detailed experiment design.

A detailed sampling plan will also be developed during the design period but is currently envisioned that a sample of farmers will be selected on the basis of farm size, farming practices (particularly in regard to the method of pesticide application) location and willingness to cooperate. The latter component as well as some of the others will require the advice and assistance of the USDA county extension agents who have had a great deal of experience with local growers and would better be able to assess their willingness to help. This will be one of the initial tasks of detailed experiment design. Figure 5.16 details how the sample selection will be made and how the data collection and other tasks will follow from this point.

Cost and loss* determination will be made by collecting data from the farmers, the NWS and various other sources such as the state departments of agriculture and MAFES. Taken together, the data supplied will fulfill the requirements of the methodology as explained in the experimental concept. That is, the combination of all data sources will supply information on the weather event, forecast, grower belief, recommended action, action taken and cost and losses incurred as well as general information on location, soil type, and the rationale for decisions made. The farmer will be required to provide certain general information and daily activity information. The general information will include:

* Soil type,

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*Previous discussions have indicated that it will be difficult to measure, with a reasonable degree of confidence, losses which are impacted by television distribution of information. It is intended, during the detailed experiment design phase, to investigate this aspect in greater detail in order to determine how reduced losses can reliably be measured.

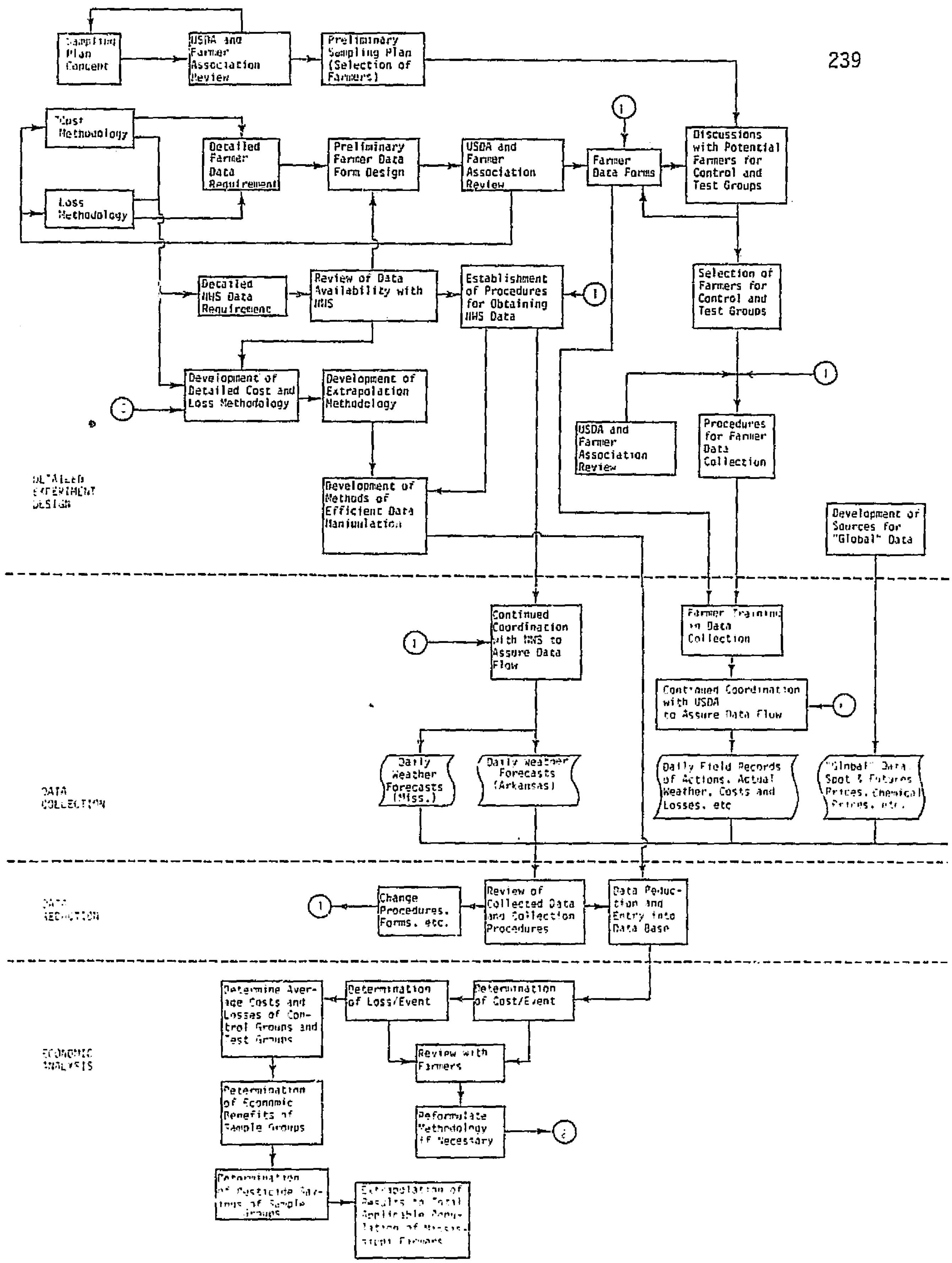


Figure 5.16 Functional Flow of Mississippi Cotton Crop ASVT (Economic Experiment)

* Growing practice (solid, skip row or other),
* Average yield,
* Pesticide application method,
* Cost of application,
* Type and cost of pesticide used,
* Cost and method of defoliant used,
* Wage rate,
* Acreage planted in cotton,
* Field location,
* Scouting techniques used,
* Personnel used for scouting,
* Cost of scouting, and
* etc.

The daily information required from farmers would include:

* Recommended pest application,
* Action taken,
* If recommended not same as action why not (rain, etc.),
* Weather forecast,
* Weather occurance,
* Loss due to precipitation (acres x application rate),
* Cost of lost material,
* Crop loss (% yield reduction),
* Extent of loss (total % of effectiveness),
* Etc.

The NWS in Jackson and Little Rock will be required to supply data on the forecasts including the general and agricultural advisories and actual weather occurances. These observations are of course limited to the recording offices. The other agencies cited will be required in order to obtain data on aggregated yields costs and expected variance within the Delta.

Collection of this data will require constant contact with the individual farmers and with the National Weather Service. It must be constantly monitored and coordinated. Such efforts will allow the normalization and aggregation processes described elsewhere to run smoothly and to produce reliable results which estimate the benefit of the television information distributions to the cotton industry in Mississippi.

5.5.2 Tasks

The accomplishment of the previously described economic experiment requires the successful completion of many detailed and diverse efforts. These have been grouped into five major tasks which are described below, namely:

1. Detailed Experiment Design,
2. Data Collection,
3. Data Reduction,
4. Economic Analysis, and
5. Reporting.

5.5.2.1 Detailed Experiment Design

The detailed experiment design task can be further broken down into three distinct subtasks, namely:

1. The creation of a detailed sampling plan,
2. The development of detailed methodologies for determining the costs and losses associated with certain weather events and various farm management decisions, and
3. The determination of specific forms and methods for data collection.

The sampling plan is concerned with the determination of the specific cotton farmers who will participate in the conduct of the experiment. The specific farmer selection process must consider the desired number of samples to be included in the test and control groups. This will include consideration of the accuracy of the data and the segmentation requirements (in terms of geographic location, farming practices, soil type, farm size, etc.). A major consideration must be USDA experience with farmers and the population of farmers which are expected to be cooperative. It is envisioned that a sampling plan concept would be developed and thence reviewed with the USDA and cotton farmers associations, the result being a preliminary selection of farmers who will participate in the experiment. After completion of the determination of farmer data requirements and data forms, discussions would be held with the farmers to make a final determination of which will participate in the experiment. During these discussions, the availability of an historical data base will be ascertained for possible inclusion as part of the control group and for verification of results. The specific procedures for data gathering

will be developed with the assistance of the USDA and cotton farmers associations.

Preliminary cost and loss determination methodologies will be developed and detailed cotton farmer and National Weather Service data requirements determined. These data requirements would be reviewed with the USDA, Cotton Farmers Association and National Weather Service. The result would be the determination of the specific data needs matched with the availability of data from the farmers and the NWS. Finally, data forms will be developed which will place major emphasis upon minimizing the farmer time requirements. The data forms will be of two types, one to gather the data which may be considered as invariant during the growing season and one to gather data on the daily events, decisions and actions. Sources will be developed for obtaining "global" data such as cotton spot and future prices, etc.

The preliminary cost and loss methodologies will be developed in detail incorporating information provided by the USDA, NWS and cotton farmers associations. The cost and loss methodologies will result in the determination of the average cost and loss per event. The methodologies will be expanded to yield annual cost and loss, for both the control and test groups, in terms of number of spraying operations. The difference between these costs and losses is the annual benefit of the television dissemination of the SMS cloud cover images and related data to the cotton farmers comprising the sample. Procedures will be developed for extrapolating these results across the Mississippi, Arkansas and Louisiana cotton industries, taking into account farmer location, farming practices, weather occurrences, etc.

Last, but not least, methods will be developed for the efficient manipulation of the large quantities of data which will be collected from both the cotton farmers and the National Weather Service.

5.5.2.2 Data Collection

The data collection task is concerned with gathering the necessary data, both current and historical, from cotton farmers and the National Weather Service. Based upon the procedures which are developed for data collection and the data collection forms, participating farmers will be instructed in data collection methods and requirements. Continued coordination will be maintained with the USDA and farmers to assure the necessary data flow. It is anticipated that the primary interface with the farmers during the data collection will be the USDA. It is extremely important that the farmers maintain careful and complete daily records as per the provided data forms. It is anticipated that a significant effort will have to be devoted to farmer coordination to assure the necessary flow of accurate data.

An analysis will be performed to determine the availability of pertinent historical farmer data for incorporation into the control group data base. Appropriate data will be collected. Based upon the data sources previously established, data will be collected on cotton spot and future prices, chemical prices and other necessary data found to be common to all farmers.

Continued coordination will be maintained with the National Weather Service to assure the necessary data flow. If it is found that farmer historical data can be used as part of the control group, then historical forecast data and historical recorded event data will

be collected. In any event, during the growing seasons included in the experiments, daily weather forecasts and daily observed weather events will be obtained from the National Weather Service.

During the conduct of the experiment, continued coordination will be maintained between ECON and Colorado State University. This coordination will result in ECON being appraised of changes in information content or format so that their impact on experiment results may be taken into account.

5.5.2.3 Data Reduction

The data reduction is concerned with the review of the collected data and transformation of the data into suitable form for entry into a general data base. As data is received, it will be reviewed for correctness and consistency. If problems are encountered, data forms and data collection procedures will be reviewed and altered accordingly.

Procedures will be developed which will "flag" possible inconsistencies in data. For example, current data will be compared with historical data and between similar farms, and data which seem questionable will be noted. The farmers will then be contacted, through the USDA, to determine if indeed an error was made or data requirements were misinterpreted. This is particularly important during the early stages of data collection where it is anticipated that misunderstandings will exist and need rapid clarification.

The data reduction task is also concerned with the determination of the accuracy of forecasting of weather events which will impact farm operations and decisions of concern. In particular, it will be

necessary to establish appropriate false alarm and miss statistics. This will be accomplished by utilizing the combination of NWS forecasts, NWS actual weather observations, and farmer observations which are to be collected as part of the economic experiment.

5.5.2.4 Economic Analysis

The economic analysis is concerned with the determination of annual saving which occurs as a result of the television dissemination of SMS cloud imagery and related information to cotton farmers and based upon the data obtained from cotton farmers and the National Weather Service. Cost and loss per event will be established and segmented accordingly. The results of these computations will be reviewed with the farmers, particularly during the early phases of data collection, in order to determine errors in methodology and/or input data and to maintain quality control throughout the data collection periods. Daily costs and losses will be established for each farmer and classified by event type, and form type. At the end of each growing season (including historical seasons), average costs and losses will be determined so that annual costs and losses can be established for the control and test groups. The results of the control and test groups will be compared and the annual demonstrated savings (both dollar savings and chemical savings) will be established. These savings, based upon the sample population, will be extrapolated to total Mississippi, Arkansas and Louisiana cotton industry annual savings, taking into account farm geographic locations, geographic weather patterns, farming practices, etc. The net result will be the establishment of demonstrated benefits and extrapolated (from the measured benefits) benefits

which are the direct result of improved spraying decisions made possible by the television dissemination of the SMS cloud cover images and related data.

5.5.2.5 Reporting

Both oral briefings and written reports will be provided Oral briefings will be given as required, however, it is anticipated that briefings will be given prior to the start of the 1978 cotton growing (spraying) season and will detail the experiment design and, in particular, the plans for control and test group data collection. Other briefings will be given at the completion of the data and economic analysis tasks associated with each growing season. Monthly activity reports will be provided. A detailed annual report will be provided at the end of each year. The annual report will describe in detail the methodology, the data collection techniques, the collected data (farmers, National Weather Service and others) and established results.

5.5.3. Schedule

The schedule for the Mississippi cotton crop ASVT (Economic Experiment) is detailed in Figure 5.17. The schedule encompasses a time period from February 1, 1978 through March 31, 1980. This enables data to be collected through two growing seasons, both being for control group and test group measurements. The consideration of two concurrent control group test group seasons allows for the highly likely possibility that it will not be possible to collect reliable data during the 1978 growing season because the cotton growers' decision processes will be evolving to adjust to the use of the newly available information.

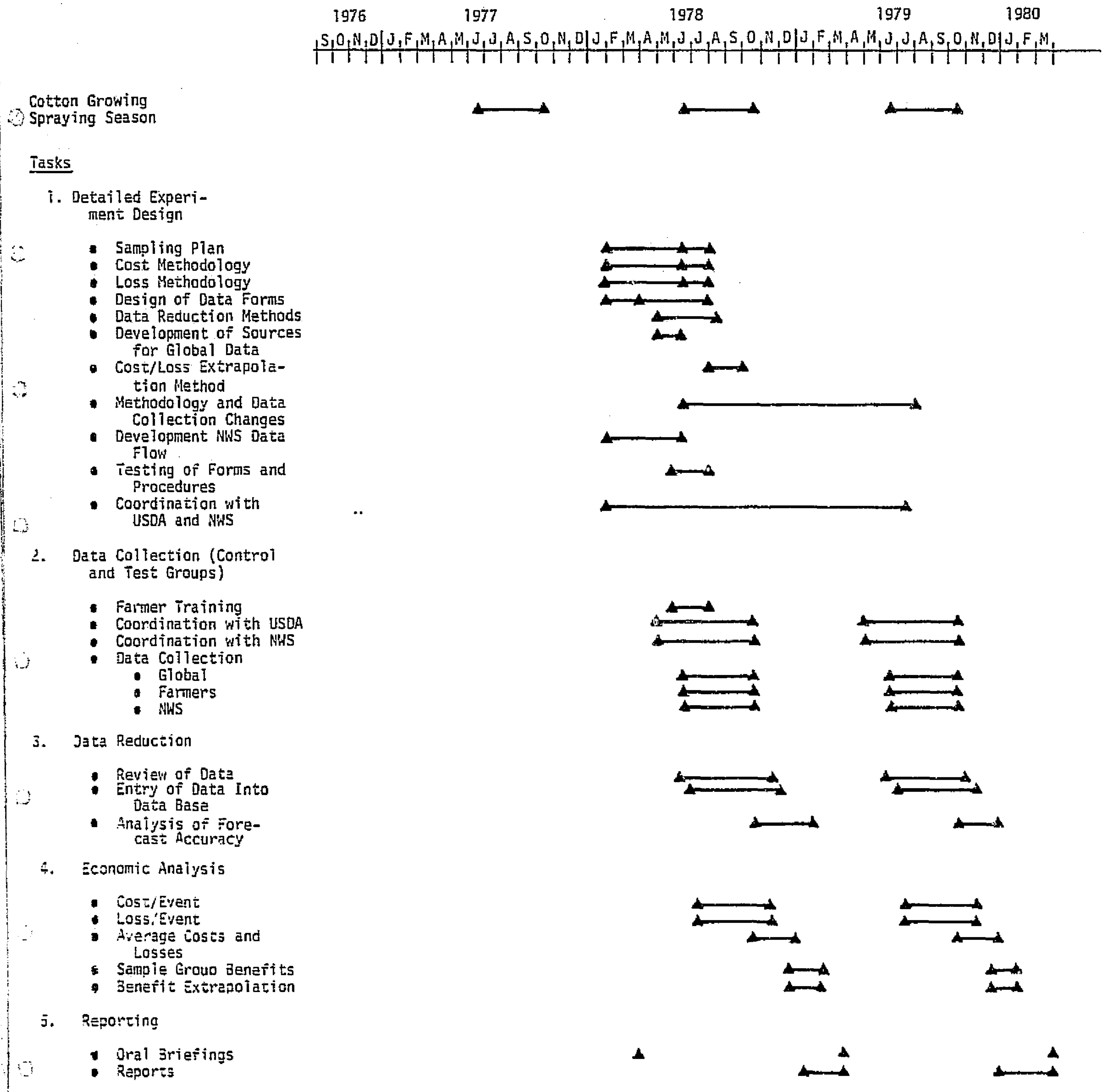


Figure 5.17 Schedule for Mississippi Cotton Crop ASVT (Economic Experiment)

The schedule must be geared to the cotton crop growing (spraying) season and the start of the Colorado State University television distribution of weather related data. It is assumed that this will start in the Spring of 1978. If the television distribution of the weather related data is delayed beyond June 1978 then the indicated schedule would be shifted to start with the 1979 (or later) growing season. It should be noted that, as in the case of the Florida ASVT, a control group could be established (in Mississippi) during the growing season which precedes the start of the television programs. This additional control group is desirable from the experience and data points of view. It is, however, a luxury which for the sake of economy, may be foregone and is thus not indicated in the schedule nor included in the budgets.

The schedule in Figure 5.17 delineates the various tasks shown in the functional flow of the experiment illustrated in Figure 5.16. In general, the detailed experiment design will take place during the first half of 1978. Data collection will take place during June through October of 1978 and 1979. Data reduction will cover approximately the same time periods. The economic analysis of the daily data will also encompass approximately the same time periods with the determination of average costs and losses and benefits associated with the sample population, and the extrapolation to all applicable growers occurring in the December-January time periods.

Finally, the schedule indicates the timing of oral briefings and annual reports. Other briefings will be provided as required,

possibly to the cotton farmers and their associations, in order to provide a feed-back mechanism to those who have had the patience and perseverence to supply the necessary data.

5.6 Management

The participants in the Mississippi cotton crop ASVT (Economic Experiment) are indicated in Figure 5.18. The participants are Colorado State University, Mississippi State University, National Weather Service (Mississippi and Arkansas), Cotton Farmers Association, Cotton Farmers, USDA (County Extension Agents in both Mississippi and Arkansas) and ECON, Inc. The roles of the participants are also indicated in Figure 5.18 and summarized below.

ECON, Inc.: ECON will design the experiment, determine the data requirements and participate in the data collection and will perform the analysis of the data which will result in the benefits of the improved forecasts to the sample population and extrapolated to the Mississippi and Arkansas cotton farmers. ECON will also assist, in cooperation with the USDA, with the general training of the cotton farmers with respect to data collection and ECON will develop and provide the data collectio forms. ECON will also, along with the USDA, continue to coordinate with the cotton farmers and the NWS in order to assure an accurate and timely flow of data.

Mississippi State University: Mississippi State University will provide general consulting support to ECON particularly in the area of cotton farmers' agricultural practices.

Colorado State University: Colorado State University, as part of the overall ASVT, will develop the basic television program

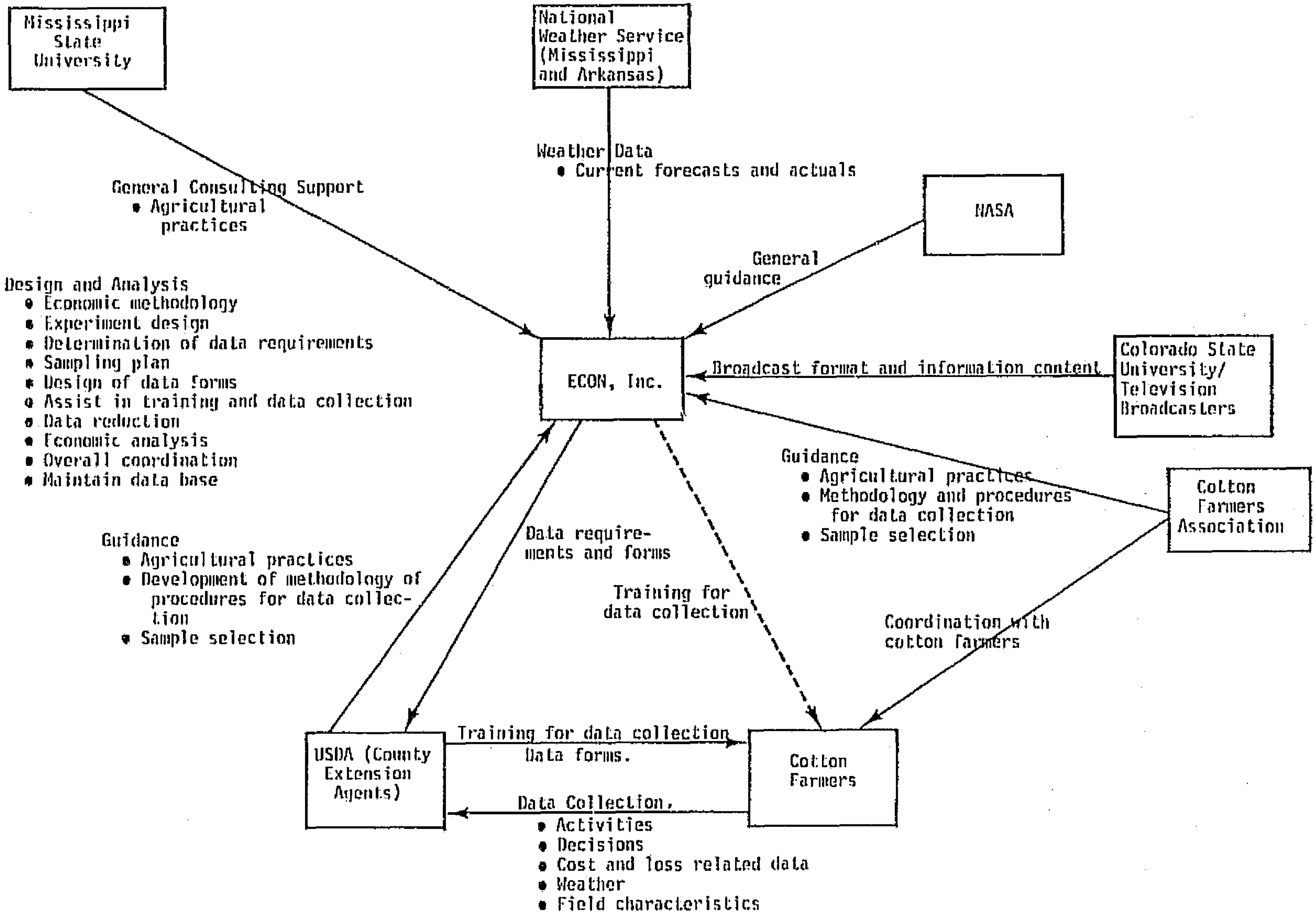


Figure 5.18 General Areas of Activity for Economic Benefit Experiment

formats and information content. The television programs will be distributed via the educational television network. As part of the economic experiment, Colorado State University will keep ECON appraised of the basic broadcast formats and information content and changes during te course of the experiment.

National Weather Service: The National Weather Service will provide weather forecasts to the cotton farmers in Mississippi and Arkansas. The NWS will furnish current forecast data and actual weather occurrence data to ECON.

NASA: NASA will provide general guidance to the participants in the experiment. In particular, NASA will direct the overall efforts of ECON and Colorado State University.

Cotton Farmers Association: It is anticipated that one or more cotton farmers associations will provide general guidance to ECON in the areas of cotton farmers' agricultural practices, methods and procedures for data collection and sample selection (in both Mississippi and Arkansas). The cotton farmers' associations will also provide general coordination with, and education of, the cotton farmers.

Cotton Farmers: The cotton farmers will provide data to ECON (via the USDA) pertaining to their activities, decisions and costs and losses associated with cotton crop spraying activities. This data will be provided on a daily basis. Weather occurrence data will also be provided on a daily basis. The growers will also provide, on a seasonal basis, general field data.

USDA (County Extension Agents in Mississippi and Arkansas): The USDA County Extension Agents, because of their detailed experience

with and knowledge of the cotton farmers and their operations, will be the direct interface with the cotton farmers. Therefore, the USDA will participate in the training of the cotton farmers for data collection and will provide the data forms to, and collect the data from, the cotton farmers. The USDA will provide general guidance to ECON in the areas of cotton farmer agricultural practices, development of methods and procedures for data collection, and provide detailed assistance in the final formulation of the sampling plan.

Because of the relatively large number of participants in the experiment and the need for continued coordination and review. it is recommended that a Coordination Working Group be established with each of the above organizations providing one member of the Working Group. It is recommended that the NASA representative serve as Chairman of the Working Group. The function of the Working Group would be to provide responsible points of contact within each of the organizations who, in turn, would see that their organizations perform and cooperate as required. The Working Group would provide the mechanism for ironing-out difficulties or coordinations. The frequency of meeting of the Working Group should vary depending upon the criticality of the efforts underway. For example, during the first several months it might be desirable to meet monthly, whereas during the latter part of the data collection phases and economic analysis phases, meetings might take place at three-month intervals. Once the experiment is initiated, it is imperative, because the weather will not wait for men, that a smoothly functioning overall organization be established of highly dedicated people to insure the timely collection of data and the orderly flow of data.

5.6.1 Manpower Requirements and Budgetary Estimates

The anticipated manpower requirements are illustrated in Figure 5.19 and manpower requirements and budgetary estimates are summarized in Table 5.5 for a twenty-six month experiment which assumes that the 1978 and 1979 cotton growing (spraying) seasons will be used to collect both the control group and the test groups data. The control group will be in Arkansas and the test group will be in Mississippi. The manpower estimates and budgetary estimates do not include time which will be spent and costs which will be incurred by Colorado State University, Mississippi State University, National Weather Service, Cotton Farmers Associations and cotton farmers in assisting with the performance of the economic experiment portion of the Mississippi cotton industry ASVT.

The manpower and budgetary estimates are provided in Figure 5.19 in terms of labor type. The role of the manpower is as follows:

- Project Director - Serve as the primary source of coordination with other participants in the experiment, direct the efforts of the technical staff involved in the design and conduct of the experiment, and participate in the design of the experiment.
- Senior O.R. Analyst - Responsible for the detailed experiment design and day-to-day performance of the experiment; serve as the senior technical man on the project.
- Statistician - Participate in the formulation of the sampling plan and review of initial data.
- Economist - Participate in the development of the economic analysis methodologies and assist with data collection, data reduction and economic analysis.
- Research Assistant - Participate in the overall experiment and assist with data collection, data reduction and economic analysis.

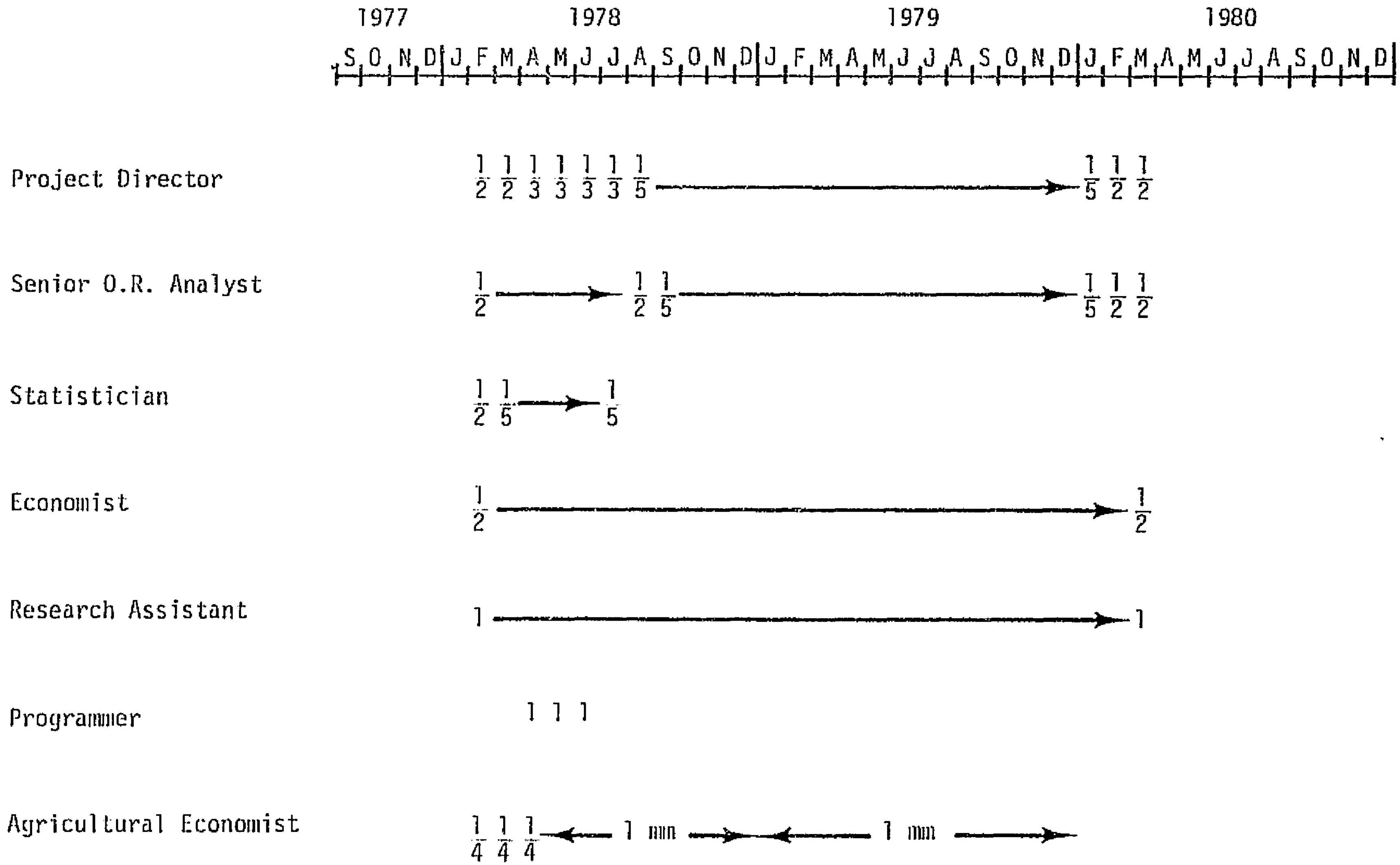


Figure 5.19 Manpower Projections for Mississippi Cotton Crop ASVT (Economic Experiment) (man months/month)

- Programmer - Responsible for the implementation of computer programs associated with the data reduction and economic analysis.

- Agricultural Economist - Provide general guidance pertaining to agricultural practices and economics.

These manpower requirements and budgets are summarized in Table 5.7. The budget required to perform the tasks directly associated with the economic experiment is $100,000-$120,000; $100,000-$120,000; and $64,000-$74,000 for the years September, 1977-August, 1978, September, 1978-August 1979, and September 1979-August 1980, respectively.

Table 5.7 Manpower Requirements (man-months/year) and Budgetary Estimates (KS/year)

	Sept.'77-Aug.'78	Sept.'78-Aug.'79	Sept.'79-Aug.'80
Manpower			
Project Director	2 - 3	2 - 3	1.8 - 2.2
Senior O.R. Analyst	3 - 4	2 - 3	1.8 - 2.2
Statistician	1.5	--	--
Economist	3.5	6	3.5
Research Assistant	7	12	7
Programmer	3	--	--
Agriculture Economist	1 - 1.5	1	.5
TOTAL (mm/year)	21 - 23.5	23 - 25	14.6 - 15.4
Budget Estimates (KS/year)	100 - 120	100 - 120	64 - 74

6. MIXED CROP ASVT (OREGON)

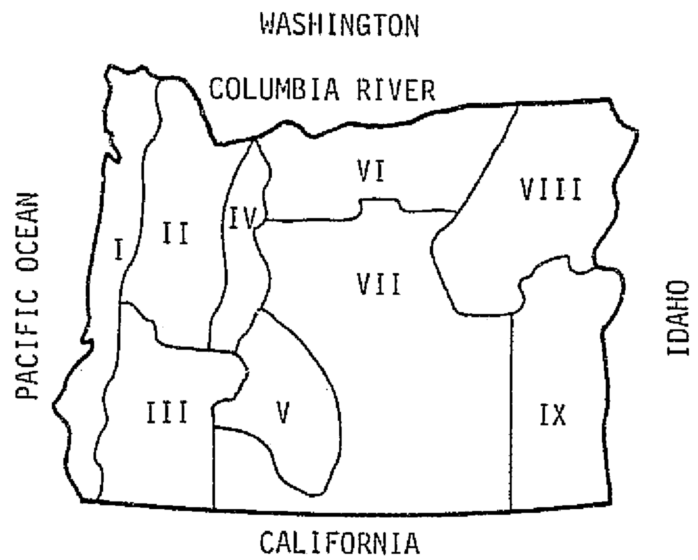
6.1 Objective

The objective of the Oregon Mixed Crop ASVT is to demonstrate the utility of television dissemination of SMS cloud cover pictures and other meteorological data to farmers and orchardists engaged in producing a rather wide range of agricultural products. This utility can be demonstrated in terms of the incremental economic benefits that might be realized as a result of the television dissemination relative to a situation where such information is not made available. Thus it is of critical importance to monitor the decisions, actions, costs and losses of farmers and orchardists and record the corresponding meteorological forecasts and actual events both prior to the introduction of television dissemination as well as after its establishment.

6.2 The Agricultural Industry in Oregon

6.2.1 A Survey of Agricultural Products

Oregon embraces a variety of topography from the Pacific Ocean to the high Cascade Mountains and interior plateaus which endows the region with nine distinctly different climatic zones as shown in Figure 6.1. As a result Oregon produces a wide range of agricultural products. The value of principal crops produced in Oregon in 1974 was approximately $800 million [32]. In terms of the value of annual crop production, Oregon is ranked 32nd among all the states within the United States [33]. The highest rank goes to California with an annual crop production greater than $5 billion, and Alaska has the 50th position



I Pacific Coastal Area
II Willamette Valley
III Southwestern Valleys
IV Northern Cascade Mountains
V High Plateau
VI Columbia River Basin
VII Central Plateaus
VIII Snake River
IX Eastern Plateau

Figure 6.1 Climatic Zones of Oregon

which is lowest in the list with an annual crop production of approximately \$2 million. The state of Washington which is climatologically somewhat similar to Oregon and produces a similarly wide range of crops has an annual crop production valued at approximately \$1.4 billion and is ranked the 20th among all the states of the United States. Thus, a question naturally arises as to why Oregon should be chosen as the host state for a mixed crop ASVT. From the economic standpoint, there does not seem to be any convincing reason. However, it is the readiness of

Oregon to introduce NOWCAST television programs to the educational TV network and the keen interest shared by some key people to fully cooperate with the experiment that makes Oregon a desirable host state. This, of course, does not imply any observed lack of interest on the part of states like California or Washington. But the difficulty of conducting this ASVT in Washington is that all the TV channels in Washington are commercial. Hence spending ten minutes in broadcasting weather information at a regular one hour interval becomes impractical.

The volume of production and the farm value of the principal crops of Oregon are illustrated in Table 6.1. From this table, the ten leading crops are selected and listed separately in Table 6.2, which reflects a mix of a wide variety of crops. In 1974, Oregon was top ranked [32] in the country in the production of winter pears, filberts, flesh plums, snap beans, peppermint oil, blackberries, boysenberries, and several seed crops (49 percent of the total United States production) including crimson clover, merion bluegrass, chewing and red fescue, bent grass, rye-grass and orchardgrass. Oregon was ranked second in the production of red clover, Kentucky bluegrass and tall fescue and sweet cherries. In terms of acres of vegetables harvested for processing, Oregon was ranked fourth. But in terms of the total value of these processed crops, Oregon was ranked third. Table 6.3 indicates the total values of Oregon's leading processed crops [34] including handling packaging and transportation for the year 1974. There are minor discrepencies between Tables 6.2 and 6.3 due to round-off errors introduced by different sources. Further, Table 6.2 indicates the production in 1974, while Table 6.3 indicates the sale in

Table 6.1 Production and Growers' Income on Principal Crops in Oregon - 1974 [32]

Crops	Production	Growers' Income (Million$)	Crops	Production	Growers' Income (Million$)
Field Crops			Fresh Vegetables		
Wheat	52,770,000 bu	242.7	Onion	178,800 T	14.6
Barley	9,000,000 bu	28.8	Sweet Corn	5,950 T	1.4
All Hay	2,491,000 T	146.9	Other	76,400 T	9.5
Sugar Beets	277,000 T	16.3			
Potatoes	891,900 T	76.5	Processed Vegetables		
Peppermint	994 T	28.8	Snap Bean	181,450 T	35.7
Hops	4,262 T	6.3	Sweet Corn	299,300 T	21.3
			Green Peas	52,900 T	10.7
Seed Crops					
			Fruits & Nuts		
Rye grass	219.5 M Lbs	39.5			
Bluegrass	15.6 M Lbs	Not Available	Apple	150 M Lbs	8.3
Chewing & Red Fescue	14.0 M Lbs	4.5	Pear	162,000 T	25.9
Orchard grass	10.2 M Lbs	3.5	Sweet Cherry	37,500 T	13.9
Tall Fescue	9.9 M Lbs	1.9	Prune & Plum	31,500 T	4.7
Bentgrass	9.2 M Lbs	3.1	Filbert	6,400 T	3.5
Alfalfa	7.0 M Lbs	5.7	Berries		
Red Clover	3.2 M Lbs	2.3	Strawberry	41.0 M Lbs	10.4
			Red Raspberry	9.9 M Lbs	3.2
			Tame Blackberry	28.0 M Lbs	6.2

T = Tons, bu = bushels, M = million, Lbs = pounds

Table 6.2 Oregon's Ten Leading Crops in Terms of Growers' Income (1974)

Crops	Growers' Income (Million $)
Wheat	242.7
All Hay	146.9
Potato	76.5
Ryegrass Seed	39.5
Snap Beans	35.7
Peppermint	28.8
Barley	28.8
Pears	25.9
Sweet Corn	22.7
Sugar Beets	16.3

1974. A major difference is found in the case of hay because the hay indicated in Table 6.3 is a subset of the "All Hay" indicated in Table 6.2.

6.2.2 Overview of Soil and Weather Distribution

Reference 35 gives some insight into the soil and weather distribution throughout the state of Oregon. These are presented below.

Soil

The soil in most of the eastern half of the state falls under the heading mollisol and subheading xeroll. Xerolls are mollisols that form in climates with rainy winters and dry summers. They are continually dry throughout the summer. This type of soil is suitable for wheat, range,

Table 6.3 Total Values of Oregon's Leading Crops Including Handling, Processing & Transport [34]

Crop	Total value including Handling, Processing, Transport (Million $)				
	Amount Paid to Growers	Payroll	Packaging Material	Other	Total
Wheat	233	13.910	-	13.910	260.820
Potatoes	74.058	29.714	41.584	47.513	192.869
Snap Beans	35.831	18.308	18.987	30.515	103.641
Sweet Corn	22.711	15.630	12.746	29.535	80.622
Grass & Legume Seeds	70.576	3.817	2.049	3.444	79.886
Pears	25.862	9.418	11.115	22.235	68.630
Hay	43.070	6.820	-	3.676	53.566
Cherry	14.693	6.256	4.093	20.947	45.989
Mint	30.119	2.075	1.383	-	33.577
Strawberries	10.475	3.412	3.926	9.725	27.538
Sugar beats	16.260	5.529	1.106	4.422	27.317
Green Peas	10.739	3.062	3,382	9.663	26.846
Other berries*	12.830	2.877	2.620	7.590	25.917
Barley	23.498	0.651		0.651	24.800
Apples	10.045	5.085	4.095	3.225	22.450
Onions	14.578	2.736	2.736	2.346	22.396
Plums & Prunes	4.725	2.730	5.135	8.185	20.775

* Includes red and black raspberries, tame blackberries, boysenberries, youngberries, loganberries and blueberries.

and irrigated crops. The western half of the state has several major types of soil--some xerolls, some ultisol humults and xerults (both low in base with subsurface clay, quite dry in summer, suitable for small grain, truck and seed crops, range and woodland), and some inceptisol umbrepts (low in base, low mineral content, some crystalline clay content, usually moist, suitable for woodland and range).

In particular, most of the dairy/poultry/truck farming is located in the Willamette Valley which is a strip on the western side of the state about 75 miles inland, from Portland downward towards the south. This area is characterized by ultisol humult and mollisol xeroll soil, suitable for a wide variety of cash crops. Most of the cash grain farming is concentrated in the NE portion of the state, where the soil is less suitable for moist-soil crops. Since most of the eastern half of the state is covered with range vegetation, it is not surprising that much of the state's cattle raising is carried on there.

Natural vegetation

Needleleaf forests of various sorts cover most of the state, with portions of the east (particularly the southeast) covered by sagebrush steppe, wheatgrass, and bluegrass.

Monthly sunshine

There is little sunshine (compared to the rest of the country) during the winter months. In the warmer months, there is much more sunshine in the eastern half of the state than in the west--the area is quite dry. The northwest coast gets the least sunshine of all, and the whole coast gets less on the average than any point inland. Evaporation follows the same pattern.

Precipitation

Most of the precipitation falls as rain during the winter months, turning to snow inland. Rain and sunshine follow approximately the same pattern (in inverse relation to each other). Along the coast, mean annual precipitation ranges from 80 to over 100 inches. The figures decrease as one moves inland, until one reaches the east (particularly the southeast) where only 8-16 inches fall each year.

Except for one or two coastal spots, rainfall in 24 hours (mean annual) is not very large, which says that the rains in Oregon are not heavy but steady. There are few heavy thunderstorms. The wet/dry extremes are very marked along the coast and in the western half of the state.

Snowfall is light along the coast, and moderately heavy in the more mountainous regions inland.

Temperature

Temperature patterns do not follow precipitation patterns as might be expected. On the whole, though, the coastal area is warmer than the inland area in the winter months, this situation is somewhat reversed in the summer months. Temperature ranges: winter, 30-50° along the coast, 20-30° in the eastern portion of the state, some areas colder; summer, mostly 60-70° all over the state.

Frost

Frost free days (approximate upper and lower bounds):

200+	along the coast
100's	irland (decreasing as one moves eastward)
60-	in mountainous areas
60 to 90	in areas surrounding mountains

Prevailing winds

The wind pattern in the Willamette Valley is significantly different from that in the eastern part of the state. This is due to the locations of the Coastal Range and the Cascades. The annual percentage frequency of wind by speed groups is shown in Table 6.4. The table does not include rare occurrences of very high speed of wind, because percentage-wise such occurrences tend to zero. The highest wind speed recorded in Portland, for example, is in the neighborhood of 60 miles per hour. The three observation stations listed in the table are located in the Willamette Valley. On the eastern part of the state, wind velocity is considerably higher and it blows predominantly from the west. Such strong winds often drift significant amounts of top soil which is predominatly sandy in nature.

Flood and drought

All but the coastal areas of the state fall into a region which is considered to be vulnerable to droughts of several years' duration. The

Table 6.4 Annual Percentage Frequency of Wind by Speed Groups

Observation Site	Speed Groups				
	0-3 mph	4-7 mph	8-12 mph	13-18 mph	19-24 mph
Portland	28	27	25	16	4
Salem	25	32	28	13	2
Medford	47	31	14	6	2

western half of the state falls into an area of above average flood potential, while the eastern half is not likely to be flooded, since it is dry during most of the year.

Land use

Cropland is concentrated mostly in the strip starting at Portland (described above) and along the northern edge of the state. Most of the western half is wooded and not generally used for farming, while the eastern half is mostly range and shrubland used for cattle grazing. Some farming does go on in all parts of the state, however.

Farms--size and area breakdown

Very small to midsize (less than 50 to 500 acres) dominate the "fertile strip" mentioned earlier. There are almost no very large farms (500+ acres) in this area. In the northeast cash-grain area, there are some small farms, but the area is dominated by very large farms. On the whole, the western half of the state contains most of the small farms, while the east holds more large farms.

Farms--breakdown by type and area

- Cash grains (wheat, barley) - mostly in the northeast part of the state
- Vegetables and fruit*
- Dairy and Poultry
- General Farms

} clustered along the fertile strip

- Livestock - mainly in the eastern half of the state, but scattered wherever there is grazing land
- Hay - many farms in the fertile strip, but hay grown in various places in the state
- Peas - all of the pea farms are located in one small area on the Washington border, in the eastern part of the state.

*Sweet corn, snap beans, peas, strawberries, apples, plums and walnuts.

- Potatos - grown in three small areas only (scattered in different parts of the state) but potato farms are highly concentrated in these areas.

Economic class of farms

The most notable fact is that statewide, 60 percent or more of all farms are part-time or part-retirement farms. These are particularly the small farms clustered along the "fertile strip."

Fertilization

Only 5 to 15 percent of all acreage (i.e., cropland and pasture in farms) is commercially fertilized. Most of the fertilization occurs in the "fertile strip" and along the northern edge of the state.

Irrigation

Statewide, 30 to 50 percent of all harvested cropland is irrigated with little or no particular pattern to irrigation.

6.2.3 Weather Sensitivity of Leading Crops

The entire process of crop production can, in a broad sense, be divided into the following operations: soil preparation, soil fumigation, planting, transplanting, fertilizing, crop cultivation, spraying insecticide, herbicide, etc., irrigation, freeze protection (especially for fruits), and harvesting. Each of these operations is sensitive to various meteorological phenomena. Though the degree of sensitiveness varies from crop to crop, a general picture [36] of the sensitivity of different operations to various weather phenomena is presented in Table 6.5.

It can be expected that weather sensitivity should be a criterion for the selection of a crop for the ASVT. However, it should be noted that for a significant number of operations listed in Table 6.5,

Table 6.5* Favorable Weather Conditions for Agricultural Operations

Operation	Soil Moisture	Soil Temperature	Air Temperature	Precipitation	Wind Velocity	Dew	Humidity
1. Soil Preparation	<80%	>32°F	—	<.05"	<30mph	—	—
2. Soil Fumigation	40%-80%	55°-80°	—	<.01"	<20mph		
3. Planting	40%-80%	>40°F	—	<.05"	<20mph	—	—
4. Transplant (Succulents)	60%-90%	>50°F	>28°F	<.05"	<15mph	—	—
5. Transplant (woody)	>80%	32°F-50°F	<50°F	<.05"	<30mph	—	—
6. Crop Fertilization	30%-80%	<50°F	—	<.05"	<30mph	—	—
7. Crop Cultivation	60%-90%	—	—	<.05"	<30mph	—	—
8. Spraying	<90%	—	—	0	<10mph	pressure & duration	
9. Irrigation	<50%		max.& min.	0	<30mph		
10. Freeze Protection	—		<32°F		direction & speed		
11. Harvesting	<90%	—	—	0	5-20mph	pressure & duration	<75%

*Source: Reference [36]

it is necessary to improve a three to five day weather forecast in order to increase the efficiency of the operation. If it is assumed that the NOWCAST program will only improve short term forecasts up to 24 hours, the operations that will be benefited become somewhat limited. A preliminary survey indicates that an improvement in the 24 hour forecast will have a measurable impact on the following operations:

1. Spraying,
2. Frost Protection, and
3. Field burning.

It should be noted that irrigation in Oregon is not dependent on 24 hour weather forecasts. This is because on the western part of the state where precipitation is plentiful, no irrigation is needed, and in the eastern part of the state where precipitation is scarce, irrigation has to be kept on schedule because rain water there is never enough anyway.

Spraying insecticides and herbicides is a common practice over a wide range of crops. However the frequency of spraying (and hence the cost of spraying) varies widely over the crops. Data supplied by the Oregon State University Extension Service indicate that of the ten leading crops listed in Table 6.2, spraying is most pronounced in the case of potatoes and pears which is followed by snap beans. For the seven remaining crops in Table 6.2, spraying is done once or twice a season costing anywhere between six dollars to fifteen dollars per acre per season. In the case of potatoes, usually seven sprays are used in one growing season: (1) wire worm control - $15/acre, (2) pestemic insecticide - $11/acre, (3) seasonal insect control - $20/acre, (4) fungicide (3X) - $20/acre, (5) herbicide (grass control) - $15/acre, (6) herbicide (general purpose) - $15/acre, (7) defoliate and/or sprout control - $20/acre. Thus the total

spraying cost for potatoes per acre per season in $116. In the case of pears, five to six sprays per season including one aerial application costs approximately $150 per acre. In the case of snap beans, typically three sprays per season costs approximately $50 per acre. Thus the natural selection of crops for the study of the impact of weather forecast on spraying should be potatoes and pears. Snapbeans can be included if there is time and manpower to accomodate it.

The savings in spraying that would result from improved forecasts will consist of two primary factors: (1) increased effectiveness of spraying thus improving insect, disease and weed control and decreasing the need for duplication efforts, and (2) fewer instances of spray being drifted by wind and inadvertently damaging crops in neighboring areas. The latter is a quite frequent occurrence--not all of which though is due to incorrect wind velocity forecasts. Sometimes personal errors are also responsible for crop damage. In 1975, approximately fifty damage litigations were filed. The amount of damage varies from case to case ranging from as low as a few trees in neighboring houses being destroyed by the drift of a chemical like 2-4-D, to as high as hundreds of acres of a high value crop being destroyed. It is felt that such damages can be decreased with improved wind forecasts.

Frost Protection

Frost protection in Oregon is limited to potatoes and orchard crops. There are no provisions for fighting frost in vegetable production primarily because vegetables are grown in the western valley region where frost is not a major problem during the growing season. But potatoes are grown from the middle of March to the middle of October

over approximately 60 thousand acres in Oregon, out of which between 5 thousand and 10 thousand acres in central Oregon, Wallawa, Crook, Deschutes, Jefferson and Klamath counties are equipped with frost protection devices that use water sprinklers. A minimum of 55 gallons of water per minute per acre must be sprinkled for frost protection. This is an operation which can be run more efficiently if the 24 hour weather forecast can be improved. Sprinkling is usually done by the Central Pivot System. The capital investment for a Central Pivot System is approximately $38,000 and typically a 160 acre lot is irrigated by one Central Pivot. These pivots are arranged such that the entire field gets covered. Figures 6.2 and 6.3 illustrate the arrangements of the pivots on the land owned by the Eastern Oregon Farming Company, and Sabre Farms, Inc., respectively.

In Oregon, pears are the most important of the orchard crops. Heaters are used for frost protection in these orchards. Typically there are 30 heaters per acre. Approximately 3/4 gallon of fuel is consumed per heater per hour. In 1974 a gallon of fuel cost 27 cents, which has since increased. Further, there is a labor cost of $10 per acre for lighting the burners and 50 cents per heater (i.e. $15 per acre) for maintenance. Combining all these expenses, the annual cost of frost protection per acre of orchard has, in the recent past, varied between $65 to $250 depending on the frequency and severity of frost. It is felt that an improvement in the 24 hour forecast can make the frost protection operation more efficient.

<u>Field Burning</u>

Grass seed is one of the important agricultural produces of Oregon as indicated in Table 6.2 and it is all grown in the Willamette

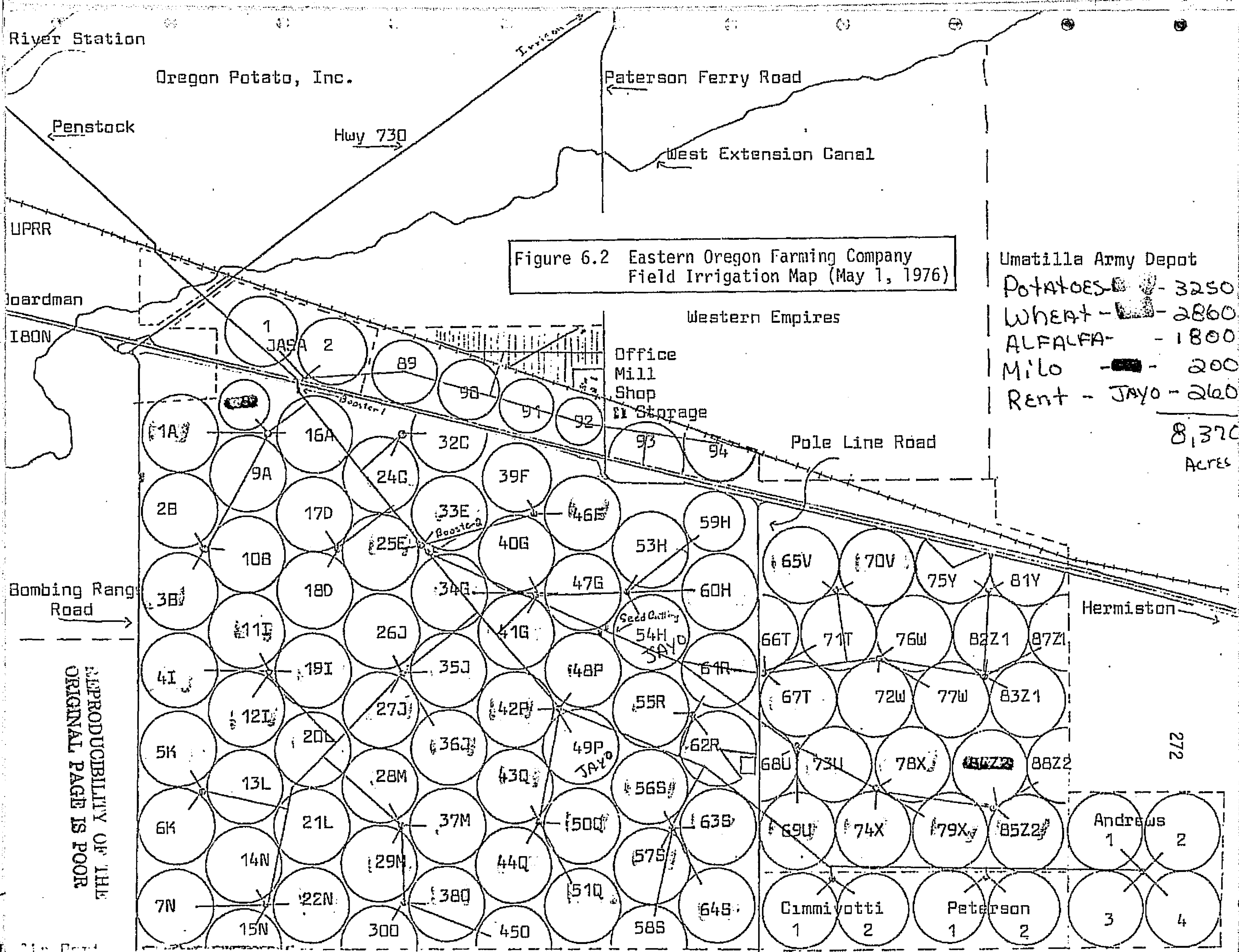


Figure 6.2 Eastern Oregon Farming Company Field Irrigation Map (May 1, 1976)

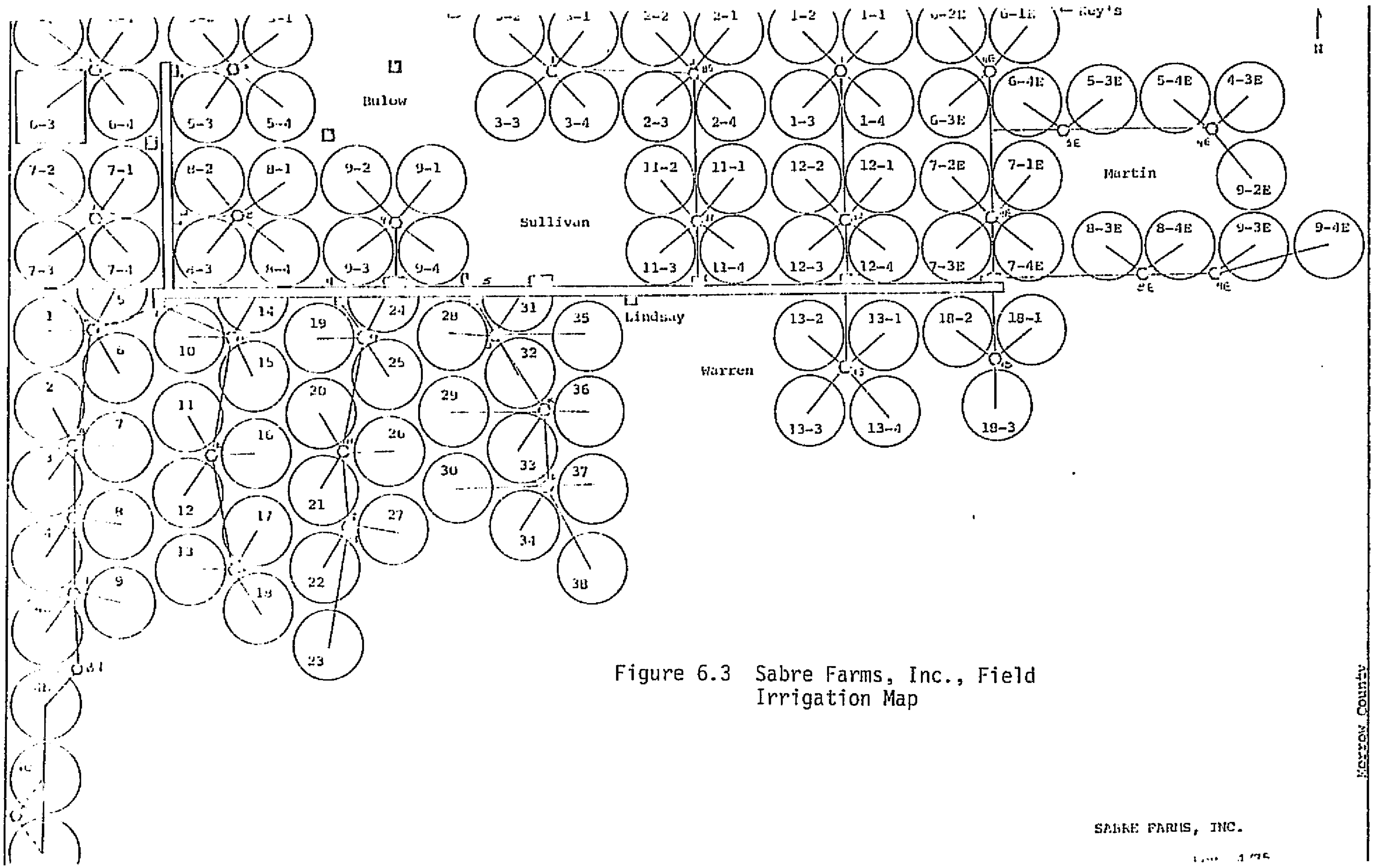


Figure 6.3 Sabre Farms, Inc., Field Irrigation Map

Valley. In order to develop healthy grass seed it is imperative that after harvesting the crop, the field be gotten rid of the funguses that, if left to thrive, would infest the next year's produce. In order to destroy these funguses, it is necessary that a temperature of at least 350° F. be maintained for at least ten seconds. Traditionally, this sanitization has been achieved by field burning. The process essentially consists of setting open fire to the field. A typical field usually takes an hour to burn off its stubble and straw. Table 6.6 indicates the thousands of acres that have been burnt annually since 1968. It should be noted that the process of registration of the acreage to be burnt was introduced in 1971 as will be discussed later. The burning season each year starts on July 15 and ends on September 30. A burning fee of four dollars per acre is charged.

Table 6.6 Acres Open Burnt in Willamette Valley

	Year							
	1968	1969	1970	1971	1972	1973	1974	1975
Burned Acreage (Thousands of acres)	315	225	252	260	270	262	283	185
Registered Acreage (Thousands of acres)	---	---	---	286	277	279	299	280

The adverse effect of field burning is the deterioration of the air quality in neighboring areas. In order to ensure better air quality three main steps have been taken:

1. Legislation to ensure a phased reduction in the acreage to be burnt,

2. Introduction of a smoke management program to closely monitor field burning and to allow such burning on a limited basis on only those days for which the weather forecast indicates minimal smoke hazard, and

3. Development of alternate ways to get rid of the funguses that do not create smoke hazard.

These three activities will now be described.

Legislation to Improve Air Quality

Major legislative changes in both policy and direction on field burning were introduced on June 29, 1971 when Chapter 563, Oregon Law 1971 was enacted. The stated purpose of the Act was to phase out open field burning in Willamette Valley as soon as a feasible alternative method of field sanitation could be made available, and in any case put a complete ban on open field burning after January 1, 1975. The 1975 Legislature, however, repealed the ban on open field burning originally scheduled by the 1971 Legislature to go into effect on January 1, 1975. The 1975 legislation (Senate Bill 311) provides for a phased reduction in the acreage to be open burned each year. To enforce the open burning acreage limitations, the legislation requires the Department of Environmental Quality to issue permits for such open burning, to monitor and prevent unlawful burning, and aid the fire district agents in their administrative duties. The bill also provides for the issurance of civil penalties with regard to open burning violations. As a result of this bill, the Department of Environmental Quality has been responsible for the direct permitting of open field fires for monitoring the acreage limitations required by the statute and direct inspection of fields as to acreage and time of burn.

Smoke Management Program

In order to control the amount of burning conducted under given atmospheric conditions and yet allow acreage amounts to be equitably distributed, the Department of Environmental Quality issues acreage releases of predetermined size called quotas. The quota size is based on the acreage registered and the historical fact that during a burning season approximately eleven days in the South Valley and approximately thirty-three days in the North Valley have favorable weather conditions to allow field burning. A percentage of the total acreage is allocated for priority use and daily priority quotas are computed on this allocated amount. This priority allocation is based on the physical location of the field with respect to certain smoke sensitive areas and the prevailing wind conditions. Typically smoke sensitive areas are those that are within three miles of major cities, within 1/4 mile and upwind of major highways and within one mile of commercially served airports. A flowchart [37] of the 1975 Smoke Management Program is presented in Figure 6.4. The number of acres burned under this program in 1975 is tabulated by date in Table 6.7.

Development of Burning Alternatives

The alternative to open burning is the use of various sanitizer equipments. Such equipments are still in the experimental stage of development. Up till now these equipments are far from the stage when they can be readily accepted as viable alternatives. They are expensive and slow in their operation. During the 1975 burning season, the Oregon Field Sanitation Committee operated four mobile field sanitizers constructed with state funds. Rear Manufacturing in Eugene also constructed

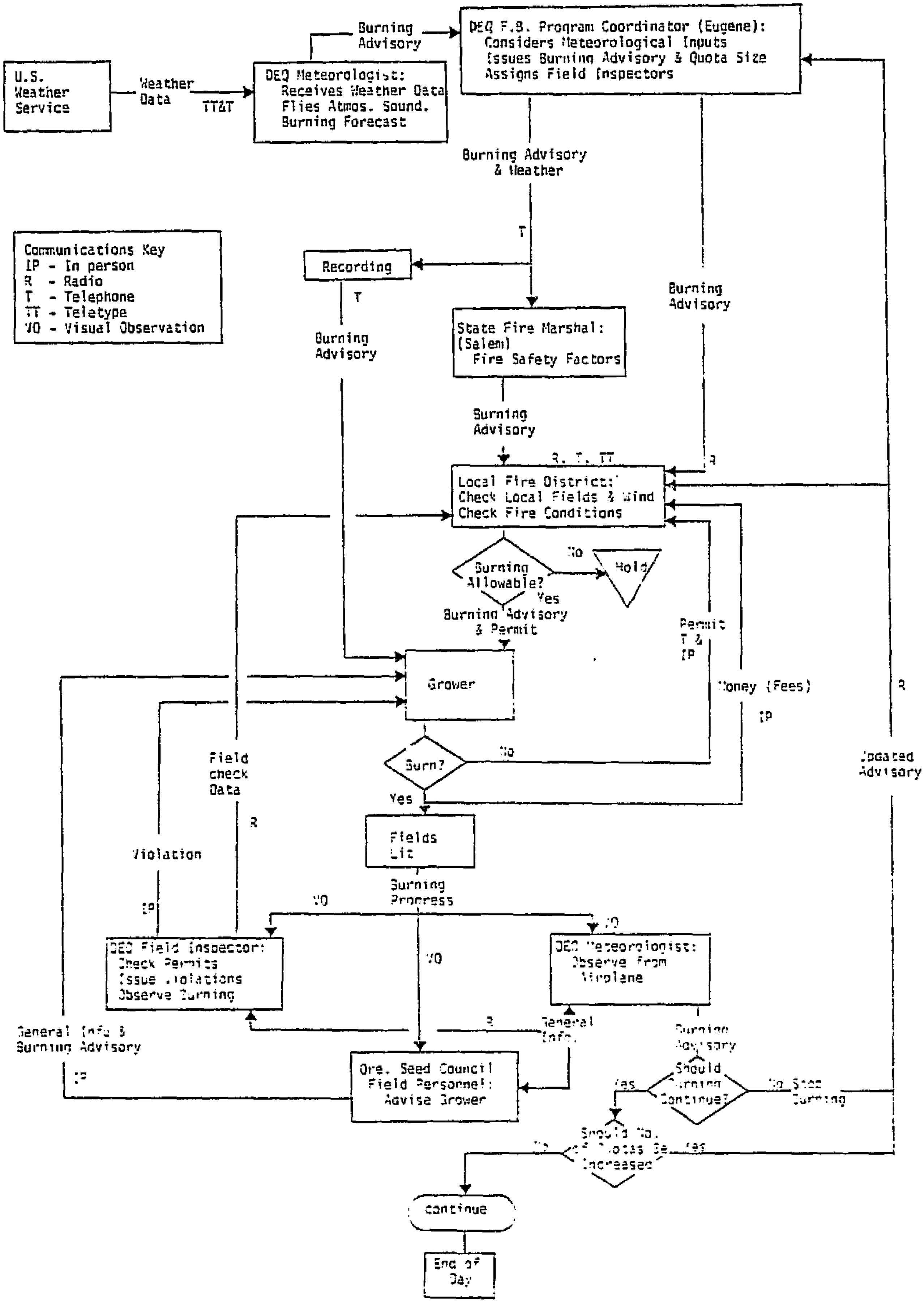


Figure 6.4. Flow Chart of Daily Operation of the 1975 Smoke Management Program (Source: Reference 37)

Table 6.7 Acres Burned By Date In 1975

Date	July	August	September	October
1		99		
2		5,056	653	1,654
3		2,676		345
4		4,915	40	
5				
6		7,682	9,719	150
7		10,635		
8		3,682	148	25
9		1,131		
10		2,044		
11		2,434	121	
12		2,741	160	
13		4,478	401	25
14		2,381	34	
15	235	918	54	14
16	670	15,359	12,725	
17	3,760	20	6,438	
18			1,373	
19	38	65	1,103	
20		1,871	997	
21		4,616		
22	60	28,882	2,617	
23		820	41	
24		196		
25	40		2,336	
26		18,138	4	
27		12,174	1,776	40
28	65			
29	15	130	25	
30	1,800		1,011	
31	1,945			
Totals	8,628	133,603	41,776	2,253

Total Burned = 186,260

three sanizizers. With all these machines only 700 acres could be sanitized. At this stage it is not known how long it would take to develop a machine that would provide a viable alternative to open field burning.

Meteorological Factors Influencing Burning Decisions [37]

The decision for open field burning depends on two meteorological considerations: (1) the daily and seasonal temperature and precipitation relationship which predominantly affects the flamability of the fields, and (2) the wind direction and atmospheric ventilation conditions that determine the degree of smoke hazard expected.

A statistic strongly indicative of the flamability of the fields is the daily maximum temperature. This value is strongly affected by the season and cloud cover and reflects the amount of solar energy reaching the surface of the earth and therefore the burning qualities of field straw. A relatively high maximum daily temperature between July and September (i.e. the burning season) is usually accompanied by low precipitation.

The prevailing wind direction and atmospheric ventilation are monitored on a continuous basis for making a judgment as to whether or not to allow burning at any given time. The position of the Eastern Pacific high pressure cell during the summer is responsible for the frequent limited ventilation and persistent north winds in Northwestern Oregon during July, August, September and October. The strength of this high pressure cell is constantly changing, so that its influence on atmospheric circulation within the Willamette Valley is constantly changing. Because of the solar heating conditions at the surface and the occasional influx of relatively cool air aloft, vertical ventilation

is sufficient to allow turbulent mixing to greater than 3500 feet about 1/3 to 1/2 of the time. It is during these times that field burning smoke has a chance to escape from the confines of the Willamette Valley. Under conditions of higher mixing levels and northwesterly or westerly winds, major impact of field burning smoke in the more heavily populated areas of the valley is usually avoided if the fields burned are sufficiently restricted by location and quality. Under such conditions some burning is usually permitted in the valley under a "marginal north" classification.

Occasionally the influence of the Pacific high pressure cell is so weakened that a mass movement of air from the south occurs. This is usually accompanied by excellent ventilation conditions and since the wind transports the smoke toward the northeast, relatively large acreages just north of Eugene can be burnt without affecting the Eugene area. Such occasions of south winds are usually classified as "marginal south" days for field burning.

Impact of Field Burning on Air Quality

The greatest air quality impact of field burning is smoke. Smoke resulting from field fires is highly visible over several miles in the form of a plume. Smoke impact is of two kinds: the direct intrusion of smoke clouds and general haze intrusions. The severity of smoke intrusions is generally categorized by the method of visibility observations. The most accurate and consistent visibility data are supplied by the Salem and Eugene Weather Services. Table 6.8 indicates the occurrence of poor visibility as observed at Salem and Eugene over the years 1968 through 1975. Poor air quality usually causes complaints

Table 6.8 Smokiness In Salem And Eugene*

	SALEM								EUGENE							
Year -	'68	'69	'70	'71	'72	'73	'74	'75	'68	'69	'70	'71	'72	'73	'74	'75
JULY																
Smoky Days	3	6	4	4	2	0	0	1	3	5	3	3	0	1	1	3
Visibility 6 mi. or less	10	3	8	16	5	0	0	5	10	12	8	12	0	2	1	8
Visibility 3 mi. or less	0	0	0	0	2	0	0	0	0	4	4	2	0	0	0	0
Visibility 1 mi. or less	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
August																
Smoky Days	5	10	10	5	8	7	1	6	4	11	7	4	7	3	4	1
Visibility 6 mi. or less	11	16	53	14	27	27	1	12	15	40	14	8	14	12	8	1
Visibility 3 mi. or less	0	3	16	2	7	7	0	3	8	30	3	3	2	0	3	0
Visibility 1 mi. or less	0	0	0	0	0	1	0	0	0	10	0	1	0	0	0	0
September																
Smoky Days	15	8	6	6	9	3	12	8	17	9	6	3	6	7	5	13
Visibility 6 mi. or less	92	66	50	19	31	14	42	28	170	51	35	9	23	17	16	44
Visibility 3 mi. or less	18	16	10	1	8	0	5	1	62	42	1	1	0	0	9	4
Visibility 1 mi. or less	0	0	0	0	0	0	2	0	6	4	0	0	0	0	0	3
October																
Smoky Days	11	13	10	11	16	7	12	0	16	15	10	3	19	9	7	1
Visibility 6 mi. or less	53	85	65	59	113	29	48	0	67	39	47	5	87	40	17	2
Visibility 3 mi. or less	5	35	16	8	31	9	1	0	50	25	3	0	7	5	4	0
Visibility 1 mi. or less	0	0	0	0	0	0	0	0	8	3	0	0	0	0	0	0
SEASON TOTAL SMOKY DAYS	34	32	30	26	35	17	25	15	40	40	26	13	32	20	17	18

Note: Smoky days are those days showing a restriction to visibility at the airport by smoke only, haze only, or smoke and haze on one or more hourly observations.

Smoky hours are those hourly observations showing restrictions to visibility by smoke only, haze only, or smoke and haze.

Smoke or haze is listed as restricting visibility when it reduces prevailing visibility to six miles or less.

*Source: Reference 37.

that are made to the Department of Environmental Quality at Portland, Salem and Eugene. Eugene appears to be specially verbal about smoke occurrences. The Lane Regional Air Pollution Authority Department of Environmental Quality Office in Eugene usually receives by far the maximum number of complaints. This is illustrated in Table 6.9.

Table 6.9 Complaints Caused by Poor Air Quality [37]

	Year							
Place	1968	1969	1970	1971	1972	1973	1974	1975
Portland	11	1645	306	113	93	46	46	4
Salem	6	88	186	81	50	48	48	110
Eugene	127	3409	1241	591	226	494	1104	647

Impact of Improved Meteorological Forecast on Field Burning

A personal interview with a meteorologist in the Air Quality Control Division of the Department of Environmental Quality indicates that since Willamette Valley lies between the Coastal Range and the Cascades, it sometimes becomes difficult to forecast the exact timing of the occurrence of good ventilation conditions in the valley. Mass movement of air from the south is usually accompanied with good ventilation. This movement is caused by a weakening of the high pressure cells on the Pacific. Thus an up-to-date cloud cover picture along the coast becomes very valuable to determine how the effect of the weakened pressure cells on the Pacific will be felt in the valley. Thus, it is expected that there will be a significant improvement in the forecast of good ventilation conditions from the television dissemination of SMS cloud

cover imagery. It has also been found during this interview that no verification has been done to determine the quality of the existing forecast capability. Hence it will be difficult to quantify the improvement in forecast quality unless elaborate forecast and observation data are collected over one or two burning seasons prior to the television dissemination of the SMS cloud cover imagery.

The economic benefits associated with any improvement in the forecast of good ventilation conditions are rather complex in nature. They are discussed separately in Section 6.2.5.

6.2.4 Current Forecast Capability

Oregon is a heterogeneous state in terms of topology, weather and agriculture. For this reason the state is divided into 13 weather forecast zones as illustrated in Figure 6.5. The national weather service forecast office is in Portland. The zonal forecast offices are indicated in Figure 6.5. The current forecast capabilities include relevant information like precipitation, air temperature, soil temperature, wind velocity, rate of evaporation, etc. These are also observed at a large number of "observation" or "recording" stations distributed throughout the state. Historical observation data are available from records kept at the National Weather Service Forecast Office. Further, hourly precipitation data are available in the publication "Hourly Precipitation Data."

Historical data are available [38] on forecast as well as observation of minimum temperature in connection with fruit-frost protection activities, which begins by the middle of March. These forecasts are distributed to four local radio stations and two TV stations at

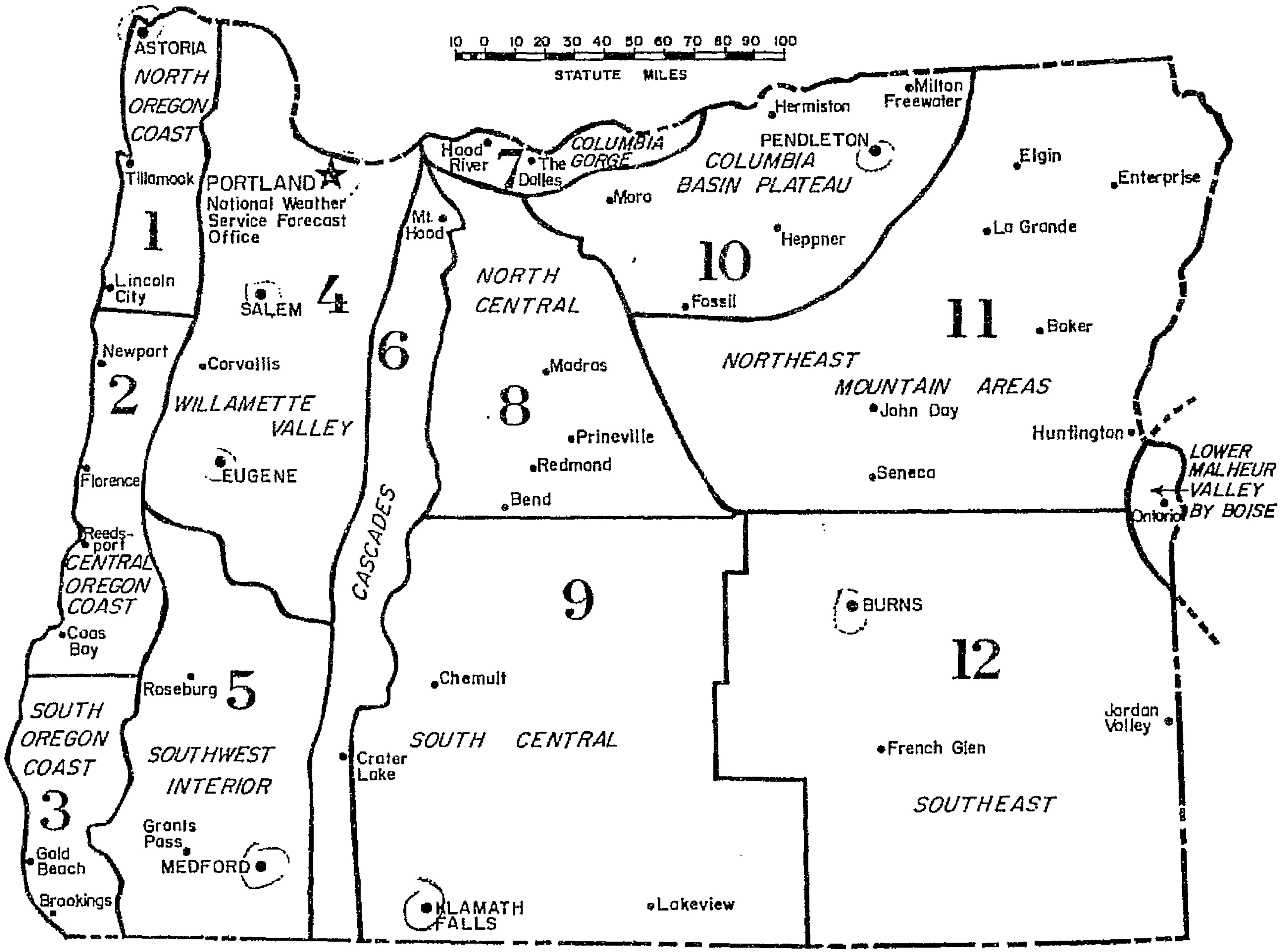


Figure 6.5 Weather Forecast Zones in Oregon, June 1975

7 p.m. The forecasts consist of a one minute taped report to provide expected low temperatures, expected firing time and an outlook of conditions for the next two to three nights. In addition to radio and TV distribution, specialized forecasts are put on two recording telephones so that growers and foremen can call an unlisted number at any time for the latest forecast. Preliminary forecasts are recorded each morning at 11 a.m. and each afternoon at 4 p.m. The final forecast is recorded at 7 p.m. On cold or threatening nights an updated report is made at midnight and later, if conditions warrant so.

For other meteorological phenomena, no sources could be identified for the historical data on meteorological forecasts that could be compared against the observation data so as to enumerate the existing forecast capability. Appendi B illustrates that if the existing forecast capability is not established before the NOWCAST experiment starts, it will be impossible to quantify the incremental benefits attributable to NOWCAST. Hence, it is extremely important to start collecting relevant data on forecast as well as observation in the immediate future prior to the start of the television dissemination of the SMS cloud imagery and related data. The type of forecast and observation data needed for this purpose are listed below.

1. Temperature,
2. Wind velocity,
3. Precipitation,
4. Smoke pollution at Portland, Salem and Eugene, and
5. Area and location of grass field burnt every day.

Table 6.10 All Potatoes, By Counties, OREGON, 1970 - 1974p+

Country	Acres Harvested					Yield per acre				
	1970	1971	1972	1973r	1974p	1970	1971	1972	1973r	1974p
	Acres					Hundredweight				
Benton........	240	320	---	---	---	230	330	---	---	---
Clackamas.....	1,000	1,000	1,600	1,600	1,650	230	270	250	290	320
Lane..........	300	270	---	---	150	230	240	---	---	320
Marion........	400	270	400	400	500	240	250	300	320	320
Multnomah.....	700	400	400	350	350	250	300	280	260	270
Washington....	200	200	200	460	460	230	250	240	270	230
Columbia......	220	220	200	200	200	210	260	240	270	280
Josephine.....	125	120	---	---	---	320	180	---	---	---
Morrow........	1,200	2,800	6,700	7,500	11,400	270	350	400	430	370
Umatilla......	4,800	2,900	4,000	3,650	7,320	280	360	410	460	410
Baker.........	500	500	300	350	350	290	280	280	310	320
Malheur.......	21,000	18,500	12,000	13,500	12,800	280	300	330	370	310
Union.........	---	---	250	310	700	---	---	250	450	400
Wallowa.......	---	150	250	355	400	---	270	270	320	430
Crook.........	2,700	1,500	900	800	1,800	310	280	380	280	340
Deschutes.....	1,300	1,000	650	600	800	290	240	380	320	340
Harney........	300	---	---	---	---	160	---	---	---	---
Jefferson.....	6,800	5,250	3,000	2,550	2,400	290	260	380	370	400
Klamath.......	11,500	11,800	9.500	9,000	8,500	310	270	360	370	340
All other countries....	315	300	350	275	220	248	240	263	375	340
TOTAL......	53,600	47,500	40,700	41,900	50,000	284	289	355	380	350

+Source: Co-operative Extension Service, Oregon State University, Corvallis

The above data are to be collected on a daily basis at the finest level of area-resolution available.

6.2.5 Economic Benefits Due to Improvements in Forecast Accuracy

It has been discussed in the previous sections that crops that should be included in the economic experiment portion of the ASVT are: (1) potatoes, (2) pears, (3) grass seed and (4) snap beans. The economic benefits that can be realized as a result of improved meteorological forecasts (as determined by the farmers and orchardists from the television dissemination of the SMS cloud imagery and related data) will now be discussed in connection with each of these four crops.

Potatoes

Reference 34 indicates that estimated sale of potatoes grown in Oregon in 1974 was 16,920,000 cwt. at a price of $4.40/cwt. This amounts to approximately $75 million paid to growers. The discrepancy between this figure and the one quoted in Table 6.1 is within range of acceptable variance due to round-off errors. A significant portion of the harvested potato is processed, and the total value of the processed and unprocessed potato sold in the year 1974 was approximately $193 million as indicated in Table 6.3. Potatoes are grown all over Oregon. Since weather and soil types are rather heterogeneous over Oregon, it therefore follows that the weather sensitivity and yield per acre of potatoes are not uniform across the state. Table 6.10 indicates the acres harvested and yield per acre by counties in Oregon during the years 1970 to 1974. Depending on the county where the potatoes are grown, the meteorological phenomena that are relevant in this study are: minimum temperature, wind velocity, precipitation and hourly temperature.

Knowledge of anticipated minimum temperature is important for protection against frost. Frost is a problem in central Oregon in Willowa, Crook, Deschutes, Jeffereson andKlamath counties. Thirteen thousand nine hundred acres were harvested in these counties in 1974. The total potato production in these counties in 1974 was approximately 4.9 million hundredweights with farm value of approximately $21 million. The "early potatoes" planted during March and April are the portion that usually suffer certain loss due to frost damage. Frost protection of potatoes is done by sprinkling water. In Figures 6.2 and 6.3, the central pivot system of water sprinkling has been illustrated. An interview with two potato farms near Hermiston (Easter Oregon Farming Company and Sabre Farms) indicates that approximately 55 gallons of water have to be sprinkled per minute per acre for frost protection. The cost of sprinkling an acre is between $100 to $125 per year. Thus, the total cost of water sprinkling is approximately $1.5 million, a fraction of which is spent on frost protection. Hence it is expected that even if the total production of $21 million in central Oregon can be increased by a small percentage by an improved frost protection scheme, that benefit can be realized without incurring any significant cost.

The wind problem is uniform throughout Oregon. However, the adverse effect of wind is not uniform throughout the state. This is because in the western region of the state in and around the Willamette Valley, wind can only hamper the spraying operation, whereas in the central region of the state where soil is much more sandy, wind can not only hamper spraying but does occasionally shear the crop as the sand drifts. In a typical year, this loss is estimated by the Sabre Farms

as somewhere between 2 to 10 percent of crop value. This loss due to shear can be decreased if a correct prediction of gust is available ten to twelve hours in advance which provides sufficient time to wet the sand using the sprinkler system to minimize the drift.

The sensitivity of spraying with respect to high wind is uniform throughout the state. It has previously been mentioned that the total spraying cost for potatoes per acre per season is $116. The adverse effect of wind on the spraying operation is felt in two ways. First, wind makes the spraying ineffective over the area where the spray is needed. Secondly, spray is drifted to a neighboring area where it is unwanted and causes damage. The Department of Agriculture at Salem keeps record of litigation caused by this damage, from which the amount of reported damage per year can be assessed. An improved wind forecast will decrease the cost on both the accounts. For spraying operation to be effective, it is necessary that the wind velocity be less than 10 knots and that the temperature remains within a critical range. The temperature information is important because depending on the chemical used, there is a critical temperature when the chemical vaporizes. Also, precipitation information is important because the chemical may get washed away. But precipitation can create a problem only in the western region of the state and not in the central region where it is scarce.

<u>Pears</u>

Pears are the most important orchard crop in Oregon with a total volume of 162,000 tons [34] sold in 1974 at a price of $159 per ton. Table 6.6 indicates that the amount paid to growers was $25,862,000.

A significant portion of pears were processed and canned. The total value of processed and unprocessed pears in 1974 was $68,630,000 making it the sixth largest dollar value crop.

Four kinds of pears are grown in Oregon: Bartlett, Anjou, Bose and Comice. The cost of producing these four types per acre is presented in Table 6.11. The cost components that are sensitive to a short range weather forecast are pest control, disease control and frost protection. The pest and disease controls are administered by spraying, and frost protection is done by heating the groves. Thus the forecasts that are of relevance are: wind velocity, precipitation and temperature. The four kinds of pears listed in Table 6.11 show some variation in costs incurred on pest and disease control, with Bose topping the list, followed by Comice. Bartlett and Anjou cost about the same in pest and disease control which is less than Comice. However, out of the four kinds, Bartlett seems to be the most common (about half of the total pear produced). For this reason, Bartlett should be chosen for the ASVT. The cost of frost protection as indicated in Table 6.11, is the same for all four kinds of pears. This is because all the samples were selected in the Rouge River Valley. Frost protection cost is expected to vary with geographical location. The geographical distribution of Bartlett pears production is illustrated in Table 6.12. It appears that Jackson County and Hood River County are the main producers of Bartlett pears. It can be expected that there will be some variation in the weather patterns between these two counties.

Table 6.11 Sample Costs Per Acre To Produce Pears*
Rogue River Valley 1974

	Bartlett	Anjou	Bosc	Comice
Cultural Operations				
Pruning	90.00	126.00	72.00	118.80
Brush removal	4.00	4.50	3.50	4.50
Fertilization	27.60	51.36	27.60	51.36
Irrigation	21.78	29.04	29.04	29.04
Cultivation	26.25	26.25	26.25	26.25
Weed control (trees & ditches)	9.68	9.68	9.68	9.68
Pest control	136.70	159.84	159.84	159.84
Disease control	36.05	15.36	36.05	26.05
Thinning	50.00	--	--	30.00
Frost protection	97.90	97.90	97.90	97.90
Miscellaneous	15.00	15.00	15.00	15.00
TOTAL PRE-HARVEST COST	514.96	534.93	476.86	568.42
Harvested Costs	261.36	255.68	255.68	259.77
TOTAL DIRECT COST	776.32	790.61	732.54	828.19
Overhead				
Depreciation	70.00	70.00	70.00	70.00
Operating cap. interest	38.68	39.40	36.50	41.28
Interest on investment	200.00	200.00	200.00	200.00
Maintenance & repair	15.00	15.00	15.00	15.00
Property taxes	23.00	23.00	23.00	23.00
Utilities & misc.	15.00	15.00	15.00	15.00
Management	80.00	80.00	80.00	80.00
TOTAL COST PER ACRE	1,218.00	1,233.01	1,172.04	1,272.47

*Source: Oregon State University Extension Service

Table 6.12 OREGON Bartlett Pears, by Counties, 1972 - 1974p*

DISTRICT & COUNTY	Production sold			Value of sales		
	1972	1973r	1974p	1972	1973r	1974p
	Tons			Thousand dollars		
DISTRICT 1	320	1,470	1,330	54	164	249
Clackamas	--	100	100	--	15	22
Lane	--	100	100	--	16	22
Marion	120	800	700	20	87	124
Polk	100	200	200	17	19	36
Washington	100	150	130	17	14	28
Other Counties, District 1	--	120	100	--	13	17
DISTRICT 3	12,280	33,920	33,450	2,012	3,926	5,761
Douglas	40	1,300	1,000	7	148	129
Jackson	12,100	32,100	32,000	1,983	3,717	5,552
Josephine	140	420	450	22	61	80
DISTRICT 4	38,400	37,610	37,200	4,156	4,451	6,374
Hood River	38,400	37,600	37,200	4,156	4,449	6,370
Other counties District 4	--	10	20	--	2	4
STATE TOTAL	51,000	73,000	72,000	6,222	8,541	12,384

*Source: Co-operative Extension Service, Oregon State University, Corvallis

The pest control program for Bartlett pears includes a dormant, delayed dormant, pink bloom and three cover sprays. Out of the six sprays, five are ground applications and one is an air application. For ground application, the tractor costs $5 an hour, the sprayer costs $5 an hour, the tractor driver is paid $2.50 an hour plus 15 percent Social Security and SAIF. Assuming that approximately 2-1/2 acres can be sprayed in an hour, the application cost per spray per acre is $5.14, which makes the cost of five ground spray applications $25.70 per acre. Air application costs $4 per acre. The material cost for all the six sprays is $107. Thus the total cost of spraying over one season is $136.70 per acre. For a spraying operation to be effective it is necessary that the wind velocity be less than 10 knots, that the spray does not get washed away by heavy precipitation and that the temperature remains at a critical level for the spray to be effective. Thus an improvement in the forecast of wind velocity, precipitation and temperature is expected to make the spraying operation more effective, thereby decreasing its cost. Another side benefit of improved wind forecast lies in decreasing the hazard of the spray being drifted to neighboring areas and causing damage. This has already been discussed in connection with the production of potatoes.

Frost protection of pears is done by heating the groves. Depending on the temperature variations from year to year, blossoms can appear any time between the middle of March to the end of April. Once the blooming takes place it becomes necessary to protect it from frost. Accordingly the season over which orchard heating is dones varies from year to year. Reference 38 indicates that in 1958,

the first night of orchard heating was February 28, and in 1940 it was April 15. These are two extreme examples. The median date of first orchard heating is March 27. In the same vein, the last night of orchard heating was as early as April 3 in 1934, and as late as May 29 in 1937. The median date of the last orchard heating night is May 14. Thus the median length of the heating season is 48 nights long. This does not mean that groves are heated all of the 48 nights. The least number of nights that grove heating was done was in 1938 when groves were heated on only three nights. The highest such number is 35 which took place in 1970. On the average, orchard heating is done 10 to 15 times in any one season. This number is expected to vary between Jackson County and Hood River County--the two main Bartlett pear growing areas. Also, in any one particular area, the frequency of heating varies between hills and valleys. For all these reasons, cost of frost protection per season has been found to vary from $65 per acre to $250 per acre. The average cost of $97.90 per acre indicated in Table 6.11 is based on 12 hours of burning per season. Usually there are 30 heaters per acre, and each heater consumes approximately 3/4 gallons of fuel per hour costing 27 cents per gallon (1974 fuel price). In addition there is a labor charge of $10 per acre and maintenance cost of $15 per acre. Thus the sum total is in excess of $97.90 per acre per season.

The economic benefit will result from the fact that with increased accuracy of temperature forecasts, unnecessary heating as well as unexpected frost damage will decrease. To be more specific, it is not necessary to forecast the temperature very accurately when

the temperature is significantly different from 32° F. If the temperature is going to be 20° F, it is not important how accurate the forecast is as long as it says that the temperature is going to be below 32° F for at least half an hour. (It is being assumed here that grove heating is necessary if the temperature stays below 32° F for half an hour or more.) Similarly, if the temperature is going to be 50° F, all that is required is that the forecast says that the temperature will not drop below 32° F. It is only when the temperature is in the neighborhood of 32° F, that forecast accuracy becomes critical. Also, it is important that temperature forecasts be made available over relatively small areas rather than an average temperature expectancy over a large area. For each day during the heating season of 1976, Table 6.13 illustrates the coldest temperature recorded among all orchards and the forecast made available for that coldest spot [38]. It appears from the table that on five days (March 31, April 15, 18, 25 and May 18) the forecast indicated that the temperature would be 32° F or higher, while the observed temperature was below 32° F. Also on one day (April 11) the forecast indicated the temperature would be below 32° F whereas the observation was for 32° F or higher. Thus, assuming that heating is needed if the temperature falls below 32° F (an over-simplified assumption used only to explain the point), there have been five possibilities of frost damage and one possibility of unnecessary grove heating. It is expected that economic benefits will result from improvements on these two statistics.

Grass Seed

Of all the agricultural operations associated with the production of grass seed, field burning seems to be the most sensitive issue--

Table 6.13 Observed Minimum Temperature and Forecast (°F) For Coldest Spot During Heating Season 1976 *

Date	Observed Minimum	Local Forecast	Date	Observed Minimum	Local Forecast	Date	Observed Minimum	Local Forecast
March 19	27	24	April 1	27	24	April 25	28	32
20	29	22	2	23	21	26	26	26
21	26	25	3	27	30	27	32	27
23	29	25	4	29	28	28	31	30
25	29	26	9	27	29	29	32	37
26	30	30	11	32	30	May 3	31	31
27	28	23	14	27	26	6	31	31
29	26	27	15	31	33	11	32	35
30	30	25	16	29	26	15	32	33
31	31	37	17	31	31	17	32	36
			18	30	33	18	31	32
			19	31	26	20	30	30
			23	29	31			

*Source: Reference 38.

both meteorologically as well as politically. The first public regulation of air quality in Oregon was enacted in 1969 with the purpose of improving air quality by controlling open field burning in the Willamette Valley. The Department of Environmental Quality was given the responsibility of administering this control through meteorological monitoring, daily acreage burning quotas and a voluntary farmer-initiated aerial Sky Watch program. In 1971, the Oregon Legislature passed a bill which put a ban on open field burning after January 1, 1975 contingent upon the development of satisfactory alternatives. No such satisfactory alternative has yet been found. Consequently, the Oregon legislature passed Senate Bill 311 which established a policy of phased reduction of acres to be burnt until 1978 as indicated in Table 6.14 along with a gradual increase of burning fees. Meanwhile the development of mobile

Table 6.14 Maximum Acres Allowed to be Burnt [39]

Year	Acres	Burning Fees/Acre
1975	234,000	$3.00
1976	195,000	4.00
1977	95,000	5.50
1978	50,000	8.00

field sanitizers is continuing, but has yet to attain economic feasibility, and the environmentalists, especially in Eugene, continue to be highly verbal about the adverse effects of air pollution caused by smoke due to field burning. In this context, one has to determine the economic benefit associated with improvement in meteorological forecast that might

decrease smoke hazard by accurately determining the time when atmospheric conditions will favor the escape of the smoke.

There are two aspects to the problem. One is the economic implication of the grass seed industry being gradually phased out or the impact of higher costs and hence prices. The other is the discomfort and health hazard caused by air pollution. Both are difficult to quantify. The future of the grass seed industry beyond 1978 is uncertain. An improvement in the meteorological forecast will certainly lead to a corresponding improvement of the smoke management program. If the improvement is of such magnitude that acceptable environmental quality is assured, it can be expected that the grass industry will not be phased out beyond 1978. Otherwise the industry will probably phase out which will impact the commodities market in a number of ways. Oregon supplies about 50 percent of the world's grass seed production. This is the result of the cool moist spring favoring seed pollination and the warm dry summer days enhancing seed maturation which provides the Willamette Valley with a comparative economic advantage in producing premium quality grass seeds. If the grass seed production is shifted to some other area, this economic advantage will be lost which, in turn, will shift the equilibrium price of grass seed to some other point on the demand-supply curve. Further, the land in Oregon that now produces grass seed, if utilized to produce some other crop, will have an impact on the commodities market. Thus the economic impact of phasing out grass seed production will have to be expressed in terms of changes in the consumer surplus and producer surplus associated with both grass seed as well as its replacements brought about by their new price

equilibrium. Naturally, the magnitude of this economic impact will depend on the severity with which grass seed production is curtailed which in turn, depends on the amount of improvement in air quality that can be realized through improved meteorological forecasts.

The other aspect of the problem, as mentioned earlier, is the social benefit associated with improved air quality. Tourism is Oregon's number three industry. But tourism does not seem to be significantly affected by field burning since tourists are attracted to the mountains and the beaches. It is only those people with respiratory ailments forced to remain in the Valley during the field burning season that are the principal losers. Thus a measure of the social benefit associated with improved air quality is the amount by which the cost of in- and outpatient medical services for respiratory troubles can be decreased plus the amount by which the production work of people can be increased due to their keeping better health. To establish this benefit, a large data collection effort will be required to establish which portion of respiratory illness can be attributed to field burning as against other polluting factors like automobile and industrial exhausts.

Snap Beans

Of the four crops suggested for this study, it is felt that the expected benefit associated with the production of snap beans is the smallest. This is because while in the case of potatoes and pears half a dozen sprayings are needed every season, snap beans need only a very few sprayings. Further, unlike potatoes and pears, snap beans do not suffer any frost damage worth mentioning. Table 6.15 indicates the distribution of snap bean production and value of sale on a county basis.

Table 6.15 Oregon Snap Beans for Processing, 1972-1975p

COUNTY	Harvested Acres				Yield per Acre			
	1972	1973	1974r	1975p	1972	1973	1974r	1975p
	acres				tons			
DISTRICT 1	33,850	40,550	42,470	31,300	3.7	4.3	4.2	4.2
Benton	3,000	3,600	3,700	2,800	3.8	4.1	4.0	4.1
Clackamas	550	600	500	400	4.5	5.5	5.9	4.1
Lane	3,500	4,200	4,900	3,800	2.8	5.2	4.2	4.8
Linn	3,500	4,000	4,200	3,400	3.8	4.0	4.0	4.1
Marion	17,700	21,150	22,000	16,050	3.8	4.3	4.3	4.1
Multnomah	700	600	400	250	4.6	4.3	5.0	4.1
Polk	900	1,800	1,970	1,300	3.0	4.2	4.2	4.2
Washington	1,000	1,300	1,400	900	3.8	4.1	4.5	4.3
Yamhill	3,000	3,300	3,400	2,400	3.8	4.2	4.2	4.2
Other Counties	1,150	1,450	1,130	1,100	3.4	2.5	3.6	4.5
STATE TOTAL	35,000	42,000	43,600	32,400	3.7	4.3	4.2	4.2

COUNTY	Production				Value of Sales			
	1972	1973	1974r	1975p	1972	1973	1974r	1975p
	tons				thousand dollars			
DISTRICT 1	126,000	175,680	179,155	132,115	13,986	18,948	37,186	22,252
Benton	11,500	14,665	14,675	11,450	1,277	1,604	2,980	1,845
Clackamas	2,500	3,315	2,975	1,635	278	342	605	[illegible]
Lane	9,900	21,865	20,650	18,255	1,099	2,392	4,364	3,322
Linn	13,200	16,065	16,660	13,900	1,465	1,393	3,471	2,340
Marion	67,700	90,355	93,585	66,480	7,515	9,463	19,500	11,218
Multnomah	3,200	2,590	1,985	1,020	355	272	424	170
Polk	2,700	7,590	8,215	5,450	300	775	1,655	906
Washington	3,800	5,320	6,245	3,865	422	586	1,335	537
Yamhill	11,500	13,915	14,165	10,060	1,277	1,421	2,852	[illegible]
Other Counties	3,900	3,670	4,045	4,985	433	422	736	781
STATE TOTAL	129,900	179,350	183,200	137,100	14,419	19,370	37,922	23,033

r - Revised. p - Preliminary.

SOURCE: Extension Economic Information Office, Oregon State University.

The three meteorological factors that are of importance with regard to the spraying operation are wind velocity, precipitation and temperature. The first two factors are important because the spray is not intended to be blown or washed away. The third factor (i.e., temperature) is important because in order for the chemical to be effective, the temperature ought to be within a critical range. The benefit due to improved forecasts is realized due to two reasons. First, if the spraying is done under more favorable weather conditions, the spray becomes more effective. Secondly, with improved forecasts on wind velocity, the unwanted drifting of spray and consequent damage to neighboring crops becomes less frequent.

An interview with the Agricultural Extension Service revealed that the cost of spraying varies approximately between \$25 to \$50 per acre per season. It immediately follows from Tabel 6.15 that the total cost of spraying in a season of all the snap beans in Oregon is somewhere between \$750 thousand and \$1.5 million. As an initial estimate if it is assumed that 10 percent of the total spray is lost due to weather, the weather loss in a typical year is between \$75,000 and \$150,000. If it is further assumed that improved forecasts decrease the loss by 10 percent, the resulting benefit will be somewhere between \$7.5 thousand and \$15 thousand.

6.3 Experiment Concept

6.3.1 Overview

The Synchronous Meteorological Satellite currently in orbit is furnishing meteorological data to ground receiving stations. Some of these data, after preliminary processing, appear at the National

Weather Service station at Portland. More frequent dissemination of these data both within the NWS and the Extension Services as well as to a wide range of users through the Educational TV network will, in all probability, improve the capability of an individual user to tailor the NWS forecast to suit his specific requirements. Further the NWS Agricultural Meteorology Office at the Oregon State University at Corvallis will be benefited by the more frequent and up-to-date meteorological data made available.

The forecasts that are of relevance to the mixed crop ASVT are: (1) temperature, (2) wind velocity, (3) precipitation, and (4) the smoke clearing conditions in the northern and the southern parts of Willamette Valley. Temperature forecasts are important for frost protection of a few principal crops like potatoes and pears. Also temperature forecasts are important for the spraying operation of potatoes, pears and vegetables among which snap beans top the list. The importance of temperature in spraying arises from the fact that for a spray to be effective the temperature should be within a critical range. The spraying operation is also affected by precipitation and wind velocity. In addition, forecasts on wind velocity are important to reduce the shearing of potatoes caused by the drifting of sandy soil. Wind velocity is also an important factor in determining the smoke clearing conditions in the Willamette Valley. The other important factor in determining the smoke clearing condition in the valley is the presence or absence of atmospheric inversion conditions.

It should be noted tha the objective of the Oregon ASVT is actually twofold, namely (a) to demonstrate the impact of the timely distribution of satellite derived data upon grower decision making and

resulting activities undertaken and (b) to measure the resulting economic benefits.

In order to measure either of the two, it is necessary to establish and thence compare the results that can be obtained with and without the improved information. This implies establishing two separate groups, namely a test group consisting of those that have access to the improved information and a control group consisting of those that do not have access to the improved information. Since the whole state of Oregon will have access to the improved information after it is introduced, it is not possible to establish a control group and a test group simultaneously in the state of Oregon. This implies that the necessary isolation between the two groups must be obtained through geographic and/or time displacement. Since geographic displacement within the state of Oregon is not possible, it is theoretically possible to establish a control group outside Oregon, in a state like Washington or California. But the problem of choosing either of these two states is that there are variations in weather as well as farming practices. Moreover, the problem of field burning is unique to Oregon and cannot be replicated in Washington and California. Thus, it is preferrable to establish a control group by time displacement. The time displacement can be either (or both) backward in time or (and) forward in time--the former relying on historical data and the latter relying on at least one season of data collection before the television distribution of SMS and related data is initiated.

The use of historical data for the control group has certain difficulties. There are historical data available on the forecast as

well as observation of frost, but no source of historical forecast data on the other meteorological events (e.g., wind velocity, smoke clearing condition, etc.) appears to exist. Further, there is a general lack of detailed data necessary to establish the pertinent costs and losses.

It is therefore highly desirable to establish a control group for each crop to be included in the experiment by selecting a number of users during the 1978 growing season (assuming that the television distribution of SMS and related data will commence early in 1979) and using historical records, as appropriate, to increase the sample size. The same users that participate as part of the control group could thence participate in the test groups during the 1979 and other future growing seasons. The experiment plan described in a later section is predicated upon this approach.

The basic concept of the experiment is as follows. During the 1978 growing season, the National Weather Service will provide the meteorological forecast data and the corresponding observation data without the farmers and orchardists having the benefit of the hourly display of the SMS and related data on the educational TV network. During this time it will also be necessary to collect the economic data (cost, loss, etc.) from the users. This set of data will be analyzed by ECON to evaluate the cost and loss associated with the forecast capability. ECON will also try to add to the sample size of the control group any reliable historical data available on day to day weather forecast, actual weather observation, cost and loss.

The same processes as performed during the 1978 growing season will be repeated during the 1979 and 1980 and possibly following growing seasons. It is assumed that the hourly TV broadcast of SMS and related data will be introduced with the start of the 1979 growing season. It is felt that a minimum of two growing seasons of test group experience is required since it is likely that during the first season, growers will be learning to adapt their decisions and actions to the improved information. Thus it is likely that the 1979 growing season will be a transient with the steady state being approached by the 1980 growing season. The analysis of the test group data will follow the same pattern as that of the control group data. A comparison of the test group and the control group--both properly normalized--will indicate the benefit associated with the television dissemination of the SMS and related data.

The concept of the grass field burning experiment requires a special mention. By Senate Bill 311, the total area of grass seed producing fields to be burned will decrease significantly over the next two years. Beyond that period, the future of the grass seed growing industry is uncertain because it depends on the improvement in the air quality realized through improved meteorological forecasts. As mentioned earlier there are two areas in which the economic impact will be felt (1) social benefit due to decreased respiratory ailments and (2) economic benefit associated with the continuation of grass seed production at a relatively low cost. In order to establish the social benefit it is essential to collect data over the next two years on respiratory ailments reported, the smoke content in the air, and the area of the fields burnt in order to correlate how much of respiratory

problem is due to field burning as against other forms of air pollution both before and after the introduction of the dissemination of SMS data.

In order to establish the economic impact of improved meteorological information on the future of the grass industry, it is necessary to develop an econometric model to forecast the futures price of grass seed and of any replacements that may be grown as an alternative to grass seed so as to evaluate the associated benefits in terms of consumer surplus and producer surplus. This model is outlined in the following section. It should be pointed out that the development of this econometric model is needed as a tool to enumerate the economic consequences of the uncertain future of the grass seed industry. As such it should be started as a self-contained effort in the immediate future and the data obtained from the control and test groups used as input data to the model.

6.3.2 Methodology

The scope of the Oregon mixed crop ASVT, as discussed earlier, has four major components:

1. Frost protection for potatoes and pears,
2. Spraying on potatoes, pears and snap beans,
3. Protection of potatoes from sand drift shearing, and
4. Burning of fields producing grass seeds.

The Frost Protection experiment is identical to the Florida citrus crop ASVT and hence the same methodology as is described in Section 4. is applicable. The spraying experiment is identical to the Mississippi ASVT on cotton as described in Section 6. and hence the methodology is basically the same.

The methodology for estimating the benefit associated with the protection of potatoes from shearing produced by sanddrifts will now be discussed. In the event of a forecast for high wind velocity, the user can respond in any one of the following fashions:

1. Take protective action by soaking the soil using water sprinklers,
2. Ignore the forecast, and take no protective action,
3. Find himself incapable of taking the proper protective action because of too short a notice, or
4. Find himself incapable of taking any protective action due to other constraints like malfunctioning of the sprinkler system, scarcity of water, etc.

The only expenses of concern are those associated with the cost of protection and the losses which result from inadequate or lack of protection. Thus, it is evident that the problem of protecting potatoes from sanddrift shearing is analogous to the problem of protecting the citrus crop in Florida from frost damage. The difference lies in the fact that while in frost protection the critical meteorological factor is temperature and the protection mechanism is grove heating, the corresponding factors in shearing protection are wind velocity and water sprinkling. Hence the same methodology as described under Florida Citrus Crop ASVT (Section 4.) is directly applicable in this case.

The methodology for estimating the economic benefits associated with field burning is different from the ones described in the ASVTs on Florida and Mississippi, and will now be discussed.

Figure 6.6 illustrates the linkages among various social and economic factors that have to be considered to evaluate the benefit associated with a prescribed forecast quality. The forecast quality

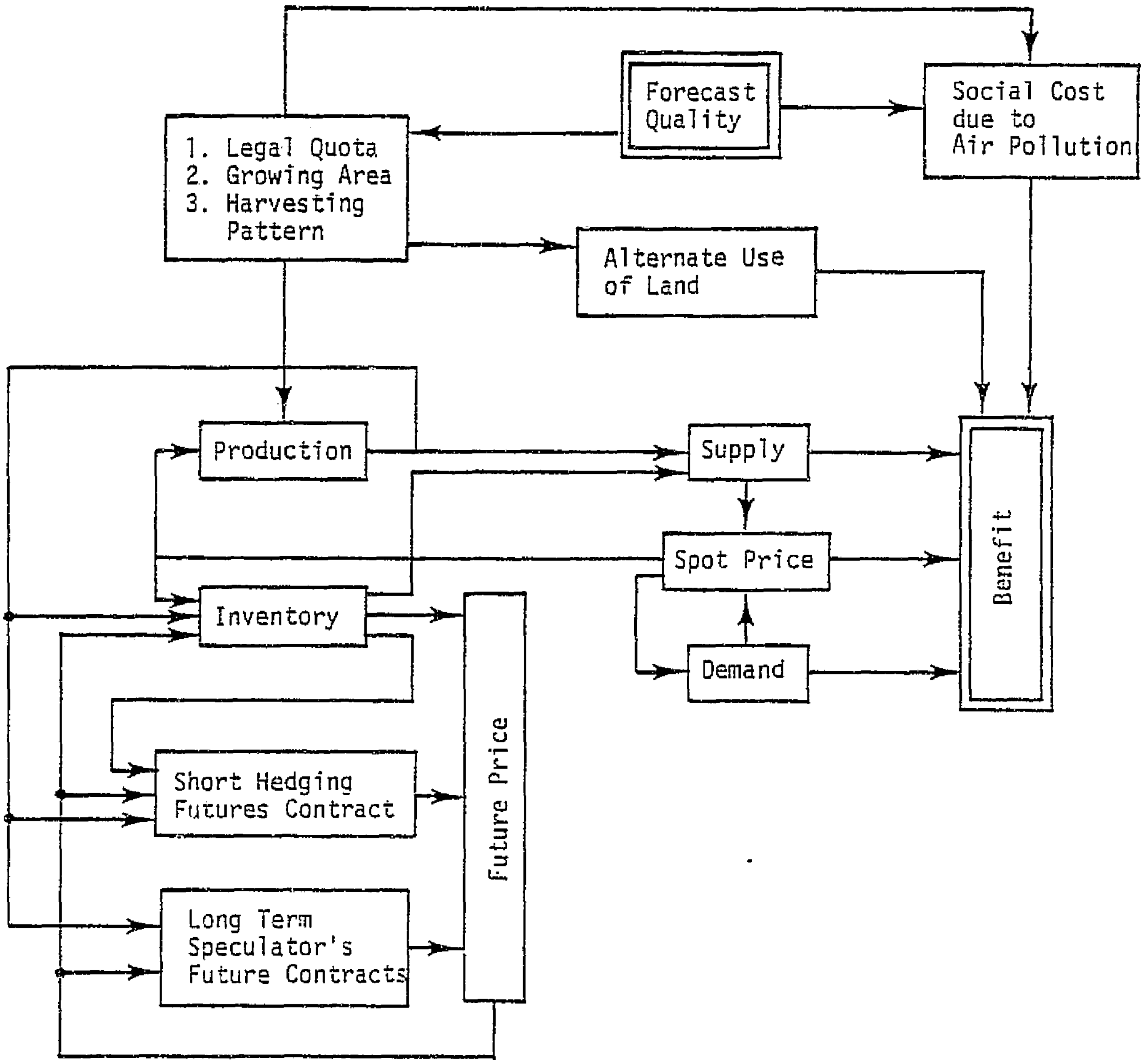


Figure 6.6 Econometric Model for Estimating Impact of Meteorological Forecast on Socio-Economic Consequences of Grass Seed Industry

directly influences the level of atmospheric pollution caused by field burning which in turn has an effect on the social cost due to healt hazard. Forecast quality is also an important factor contributing to the future of the grass seed industry (i.e., legal constraints on the legal quota on burning, etc.) which has two impacts--one purely economic and the other environmental. The economic impact is felt due to changes in production which influence supply of grass seed, inventory, short-term hedging, long-term speculation, spot price, future price, etc., which are interrelated among themselves as illustrated in Figure 6.6. The economic benefit can be expressed in terms of consumers surplus and producer surplus which are functions of demand, supply and price structure of grass seed as well as of other crops that might be produced instead of grass seeds as an alternative. The total impact of the grass seed industry is this economic benefit minus the social cost due to health hazard which can be expressed in terms of medical expenses and productive time lost due to ill health. The purpose of the econometric model is to provide a tool to determine how the total impact of grass seed industry is dependent on the quality of the meteorological data and forecasts. The methodology, thus, consists of first developing this model and then applying it to both the control and test group data (before and after the television dissemination of SMS and related data) in order to establish a comparative result.

6.3.3 Cost and Loss Determination

The purpose of this section is to outline the various costs and losses that can be incurred in connection with the frost protection of potatoes and pears, the spraying operation of potatoes, pears and

green beans, and the protection of potatoes from being sheared by sand-drift. The fourth benefit area namely the burning of grass seed producing fields calls for a different kind of analysis as indicated earlier and hence is omitted from this discussion. It should be noted that the costs reflect those expenses that are incurred in the process of taking protective action against anticipated adverse weather. The losses reflect the damages inflicted by adverse weather.

Lumping the three experiments together, the cost factors can be expressed in the following general terms:

1. Cost of material consumed (i.e., water sprinkled, chemicals sprayed, fuel burnt in heaters, etc.),
2. Cost of energy consumed in owned machinery (e.g., electricity, fuel for engine, etc.),
3. Cost of labor--both employed and contracted,
4. Cost of renting machinery if not owned (e.g., airplane for aerial spraying),
5. Repair and maintenance of owned machinery,
6. Overhead, and
7. Capital depreciation (this may not be affected by forecast improvements).

To have a complete description of the cost, all the above factors have to be enumerated per acre per event.

The loss, as indicated above, is the damage inflicted by adverse weather. The extent of this damage may be limited to the particular season during which the adverse weather occurred, or it may be extended to subsequent seasons as in the case of trees partially damaged by frost. Lumping the three experiments together, the losses are listed below:

1. Amount of mature crop damaged,
2. Expected market price at which the mature crop could have been sold if undamaged,
3. Reduced price at which partially damaged mature crop is sold, assuming this salvaging can be done,
4. Amount of immature crop damaged,
5. Discounted price of immature crop damaged (i.e., price of mature crop minus the money that would have been spent in the process of growing it from the immature to the mature stage),
6. Expenses associated with getting rid of all the damaged crop (both mature and immature) that cannot be sold,
7. Expenses associated with remedial actions (e.g., reseeding if early sprout of potato is damaged, releveling ground in the case of sanddrift, extra care for a partially damaged tree, etc.), and
8. Losses expected to carry over to subsequent seasons (e.g., loss of future productivity of potatoes due to drifting of top soil, loss of future productivity of partially damaged trees, etc.).

The above losses have to be ascertained per acre per event.

6.3.4 Control Group Possibilities

In the previous section on experiment methodology, a technique of benefit measurement by comparison of test and control group results was outlined. Three different possibilities of formulating the control group have previously been mentioned: (1) geographically separated control group, (2) historical control group, and (3) temporally separated control group. Out of these three possibilities, it has been suggested that the third alternative be pursued. The various considerations that should be taken into account in order to make a comparison among the relative strengths and weaknesses of the three alternatives will now be presented. The criteria should include: (1) What is the availability

and quality of economic data? (2) What is the availability and quality of meteorological forecasts as well as observation data? (3) Is it possible to select a statistically significant sample? and (4) Will it be possible to normalize the effect of differences between the control and test groups due to variations in meteorological phenomena, forecast qualities, differences in soil types, farming practices, etc.?

6.3.4.1 Geographically Separated Control Group

The grass seed industry and the associated environmental problem due to field burning are unique to Oregon. Hence it is not possible to select any other area to serve as the control group. Potatoes, pears and snap beans are also produced in the two neighboring states namely, California and Washington, of which Washington more closely resembles Oregon in climate and soil type. So it is feasible to select Washington to serve as the control group. The difficulty lies in the fact that due to a larger volume of production in Washington than in Oregon, the farming practices are different. The use of radio communication among different farms for dissemination of weather information is much more extensive in Washington than in Oregon. Hence, it will be difficult to normalize the control and test group data to a common denominator so as to assure a fair comparison.

6.3.4.2 Historical Control Group

This consists of selecting historical data on the day to day expenses of representative farm samples as well as day to day meteorological forecast and observation data. The only complete record that could be located was the day to day temperature forecast and temperature observation for pear growers in the context of their frost protection activities. Also Sabre Farms, Inc. and Eastern Oregon Farming Company--both in the

vicinity of Hermiston--have complete records of their farm management of potato production which would reflect their costs and losses. However, there is no way to correlate these economic data with the actual and predicted wind velocities. The same can be said about the spraying operation of snap beans. In short, the historical data, at best, are incomplete. As such it will not be possible to apply the methodology developed for this study to a control group exclusively composed of historical data.

6.3.4.3 Temporally Separated Control Group

It follows from the above discussions, that the only satisfactory control group can be formed by collecting data on meteorological forecast, meteorological observation and farm management during the period prior to the introduction of the television dissemination of SMS and related data. Assuming that the television distribution of information is introduced by the end of 1978, control group data can be collected during the growing seasons of 1977 and 1978. Data collected over two seasons offers greater statistical confidence than if they are collected over one season. However, if it appears that this involves a task too elaborate for this study, at least the data collected over a minimum of one season is a must. Accordingly, it is recommended that a control group be formed by judiciously sampling the various users and collecting the forecast, observation and farm management data over at least one growing season, namely 1978. There will be four subgroups within the control group: (1) a group of potato growers, (2) a group of pear growers, (3) a group of snap bean growers, and (4) a group of grass seed growers.

6.3.5 Test Groups

The sample population of growers that will represent the control group during 1978 (i.e., prior to the television dissemination of SMS and related data) will become the test group subsequent to the introduction of the new information. A representative sample of sufficient size will be chosen to record both weather observation data as well as farm management data. Each user could be given a pad of questionnaires so that he could have a fresh copy for each weather incident. The questionnaires would then be collected, in person, once every two weeks or mailed to a central location. It might also be possible to have two levels of participation open to each user at the beginning of the experiment. One group of users would commit themselves to keep records on a daily basis. The other group would be called upon only when severities in weather conditions are anticipated. At the beginning of the growing season, seasonal variables such as heaters per acre, sprinklers per acre, fuel consumption rates, etc., will be collected. There will be four subgroups within the test group: (1) a group of potato growers, (2) a group of pear growers, (3) a group of snap bean growers, and (4) a group of grass seed growers. These will correspond to the four subgroups within the control group mentioned earlier.

The first year after the introduction of the SMS data dissemination scheme will probably be a learning period for users with only partial improvement in their respective decision processes. Thus, it is imperative that the experiment continues for at least another year.

6.3.6 Sampling Possibilities

6.3.6.1 Sample Frame

There are four groups of growers in Oregon that are included in this experiment namely, potato growers, pear growers, snap bean growers and grass seed growers. Each group will have to be sampled to create the respective representative sample populations. Thus the first task is to determine the geographical distribution of each of the four user groups. In determining these user distributions, only those users should be considered that are equipped with the means of taking protective action in the face of adverse weather forecast. Thus, in the case of potato growers, the definition of a user will have to be restricted to those that are equipped with a water sprinkling system to fight frost and wind damage. Similarly for pear growers, the users are those that have means to take frost protection actions like heating the groves.

The distribution of the protected acreage throughout the entire harvested acreage is very important in determining the target population, the survey population, and finally, the sampling frame. It is this population from which cooperative growers will be selected for participation in the control and test groups.

The survey population may be divided for sampling purposes into sampling units. The size of a sampling unit will depend on the crop in question. For example, typically there are 72 pear trees per acre which may serve as a typical sampling unit for pears. For potatoes, one central pivot sprinkler typically covers a lot of 160 acres which is also about the smallest size required for aerial spraying operation. Thus a 160 acre lot may be the sampling unit for potatoes.

There are two basic types of sampling frames, namely the area frame sampling and the list frame sampling. These sampling frames as well as the multi-frame sampling, which is a combination of the two, are often used in the collection of data for agricultural statistics. The relative advantages and disadvantages of the various frames have been discussed under the Florida ASVT. It is recommended that multi-frame sampling be used in the Oregon ASVT to define the four sample populations representing the four user groups mentioned above.

6.3.6.2 Important Factors to Include in Sampling Plan Stratification

There are a number of factors which play an important role in a successful sampling. These factors and their influence can be identified during the construction of the list frame. This prior knowledge about the population is necessary in the development of a stratified sample. The population is divided into homogeneous subsets--strata--and then only a relatively small number of observations is needed to determine the characteristics of each subset. This would be advantageous compared to the simple random sampling which requires an access to all items in the population at increased cost and difficulties of its implementation.

The following list includes some of the important variables that should form a basis for stratification:

1. Geographical location. The climate zones of Oregon as depicted in Figure 6.1 should form a basis for stratifying the growers. The crops chosen for this ASVT are primarily contained within zones II, III, VI and VII. Each zone should be treated separately so as to stratify the climatic variations. Further, in the case of field burning, the vicinity of an urban area is of paramount importance.

2. Micrometeorology. Local topography, altitude, soil type, etc.

3. Variety of a crop. Within a certain crop label there may be varieties of crop types. For example, within the label of grass seed there are a number of types like annual rye, perennial rye, blue grass, fescue, bentgrass, etc. Each has its own sensitivity towards field burning and the commodities market. These will have to be treated separately. Similarly, among pears, there are four major types grown in Oregon. They are Bartlett, Anjou, Comice and Bose. They bloom at different times and are different in their sensitivity to frost damage. It is recommended that the ASVT be restricted to Bartlett only because this is the most common type produced in Oregon. So if the sample groves produce more than one type, the Bartlett has to be selected out of the total produce.

4. Size of farm/grove. This reflects the economy of scale. It can be expected that cost per acre will be smaller for large farms (or groves) than for the smaller type. Further, large groves tend to reduce the velocity of cold winds during advective freezes and mixing of cold air components is better in larger groves. This adds to the economy of scale.

5. Age of trees. In the case of pear groves, older trees are less susceptible to injuries caused by freezing temperatures than younger ones.

6. Technology variation. There may be variations in the technology used for protection against adverse weather. For example, in the case of potato growers there are a number of different types of sprinkler systems that are in use.

7. Use of the crop--fresh or processed. If among the crops produced (potatoes, snap beans and pears) there are different varieties that are subjected to different processing systems to produce different packaged items significantly different in price, they have to be treated separately because the economics of protect/no protect decisions may be different.

8. Cooperation of growers. This variable is very important in the effort to obtain as complete a list of all measured characteristics as possible. The complete and timely return of questionnaires and cooperation during interviews are necessary for the successful collection of data. The previous experience of USDA and direct interviews will be used to stratify the sampling frame accordingly.

These seem to be the major variables influencing the protective measures. There are other variables, such as risk adversity of growers, price of fuel, future price as conceived by an individual grower, etc., which are not measured directly but have an impact on all measured variables and also on the protect/no protect strategy.

6.4 Experimental Plan

6.4.1 Description of the Experiment

The Oregon ASVT will encompass essentially four different experimental areas, each designed to demonstrate the benefits of improved weather information dissemination in the production of one of the agricultural commodities of Oregon. The first will be in the chemical spray application to potatoes, and possibly snap beans, the second in frost protection of potatoes and pears, and the third in the protection of potatoes from being sheared by sanddrift, and the final one, the field burning of grass seed debris. Each will require a different data collection and analysis.

In the area of spray application it is expected that more accurate timely weather information will allow the farmer to make better decisions on when to apply pecticides thus reducing losses due to wash-off and temperature induced efficiency loss and losses to neighboring areas due to drift. Although other yield affects may result from the dissemination of SMS data only the reduced material losses and reduced drift damage will be measured. Since it is anticipated that the television broadcasting will probably not be operational in Oregon until 1979, it would be possible to collect data from the same farmers who will be in the test group later, during the 1978 growing season for control purposes.

A detailed sampling plan will also be developed during the design period but is currently envisioned that a sample of farmers will be selected on the basis of farm size, farming practices (particularly in regard to the method of pesticide application) location and willingness to cooperate. The latter component as well as some of the others will require the advice and assistance of the USDA county extension agents who have had a great deal of experience with local growers and would better be able to assess their willingness to help. This will be one of the initial tasks of detailed experiment design.

Cost and loss determination will be made by collecting data from the farmers, the NWS and various other sources such as the Oregon Departments of Agriculture. Taken together, the data supplied will fulfill the requirements of the methodology as explained in the experimental concept. That is, the combination of all data sources will supply information on the weather event, forecast, grower belief, recommended action, action taken and cost and losses incurred as well as general information on location, soil type, and the rationale for decisions made. The farmer will be required to provide certain general information and daily activity information. The general information will include:

- crop,
- average yield,
- pesticide application method,
- cost of application,
- type and cost of pesticide used,
- wage rate,
- average planted,

- field location,
- method of determining need for pesticide, and etc.

The daily information required from farmers would include:

- recommended pest application,
- action taken,
- if recommended not same as action why not (rain, etc.),
- weather forecast,
- weather occurrence,
- loss due to precipitation or wind (acres x application rates),
- cost of lost material,
- crop loss (percent yield reduction),
- drift damage,
- extent of loss (total percent of effectiveness), etc.

The NWS will be required to supply data on the forecasts including the general and agricultural advisories and actual weather occurrences. These observations are of course limited to the recording offices.

The areas of frost protection and the protection of potatoes from being sheared by sanddrift will require a similar procedure, i.e., the establishment of consecutive control and test groups. However, the data required will vary. The required seasonal data consists of information which may be considered, for purposes of the experiment, to remain constant during the frost season and consists of

- average wage rate ($/hour),
- heater fuel consumption (gallons/hour/heater/field or orchard),
- sprinkler fuel consumption (gallons/hour/sprinkler/field or orchard),
- average crop yield (bushels/field or orchard),

- crop type per field or orchard,
- field or orchard size (acres),
- field or orchard location (including general terrain features),
- field or orchard elevation (feet),
- soil type,
- number of heaters per field or orchard, etc.

The field or orchard daily data must be collected for each night during the frost season except* on those nights where clearly there is no possible chance of frost occurring. The data consist of

- crews alerted? (yes or no/field or orchard),
- number of men employed in field or orchard (men/hour/field or orchard),
- number of heater used (heaters/hour/orchard),
- sprinklers used (sprinklers/hour/field) ,
- temperatures (°F/hour/field or orchard),
- forecast temperature (°F/hour/field or orchard),
- losses (percentage yield/field or orchard),
- tree damage (percentage of yield/orchard), etc.

In order to establish the protection costs and crop losses, other general data is necessary and need not be provided by the growers. This data consists of commodities (by type) futures and spot prices, fuel prices, etc. Again, NWS data collection on forecast and actual weather will be required.

In each case data must be constantly reviewed and close contact maintained with individual growers, NWS and other agencies to assure the immediate correction of problems which arise and uniformity of results.

*The exception is an attempt to minimize the grower data collection task.

A detailed functional flow for the spray and frost protection of the Oregon ASVT is presented in Figure 6.7. Note that this is a general form and the word "grower" is used to indicate the farmer or orchardist in the specific crop under study. "Field" is used to refer to the field or orchard used in the sample. Some of the steps included may be unnecessary in one of the experimental areas. The individual tasks are discussed in Section 6.4.2 and the schedule and participation in Sections 6.4.3 and 6.4.4, respectively. The tasks associated with econometric modeling are described in Section 6.4.2.5.

The accomplishment of the previously described economic experiment requires the successful completion of many detailed and diverse efforts. These have been grouped into five major tasks which are described below, namely:

1. Detailed Experiment Design,
2. Data Collection,
3. Data Reduction,
4. Economic Analysis, and
5. Reporting.

6.4.2 Experiment Tasks

6.4.2.1 Detailed Experiment Design

The detailed experiment design task can be further broken down into three distinct subtasks, namely:

1. The creation of a detailed sampling plan,
2. The development of detailed methodologies for determining the costs and losses associated with certain weather events and various farm management decisions, and
3. The determination of specific forms and methods for data collection.

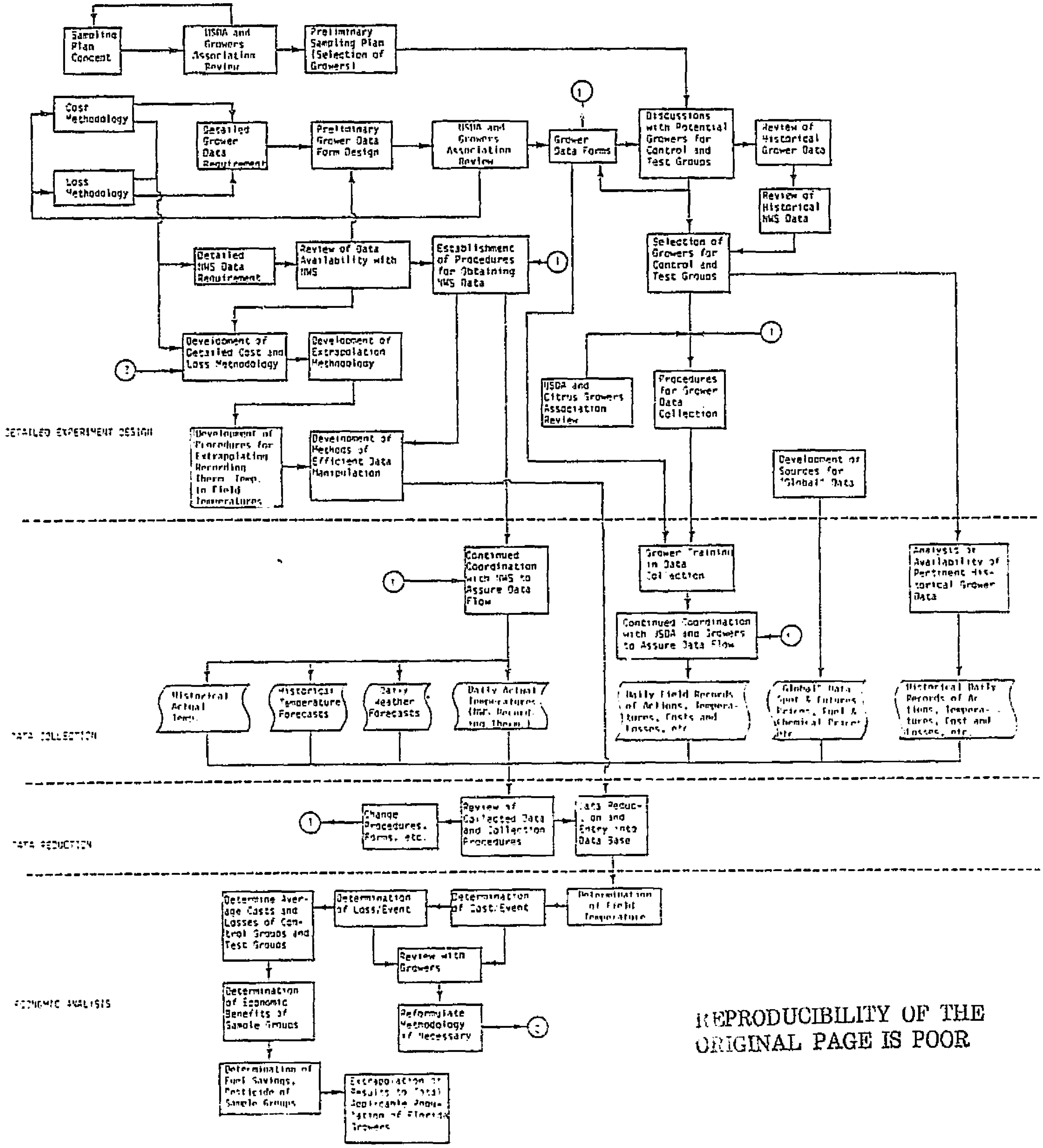


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Figure 6.7 Functional Flow of the Spray and Frost Protection Portions of the Oregon Mixed Crop ASVT (Economic Experiment)

The sampling plan is concerned with the determination of the specific farmers who will participate in the conduct of the experiment. The specific farmer selection process must consider the desired number of samples to be included in the test and control groups. This will include consideration of the accuracy of the data and the segmentation requirements (in terms of geographic location, farming practices, soil type, farm size, etc.). A major consideration must be USDA experience with farmers and the population of farmers which are expected to be cooperative. It is envisioned that a sampling plan concept would be developed and then reviewed with the USDA and growers' associations, the result being a preliminary selection of farmers who will participate in the experiment. After completion of the determination of farmer data requirements and data forms, discussions would be held with the farmers to make a final determination of which will participate in the experiment. During these discussions, the availability of an historical data base will be ascertained for possible inclusion as part of the control group and for verification of results. The specific procedures for data gathering will be developed with the assistance of the USDA and growers' associations.

Preliminary costs and loss determination methodologies will be developed and detailed grower and National Weather Service data requirements determined. These data requirements would be reviewed with the USDA, growers' associations and National Weather Service. The result would be the determination of the specific data needs matched with the availability of data from the growers and the NWS. Finally, data forms will be developed which will place major emphasis upon minimizing the

growers time requirements. The data forms will be of two types, one to gather the data which may be considered as invariant during the growing season and one to gather data on the daily events, decisions and actions. Sources will be developed for obtaining "global" data such as spot and future prices, etc.

The preliminary cost and loss methodologies will be developed in detail incorporating information provided by the USDA, NWS and growers associations. The cost and loss methodologies will result in the determination of the average cost and loss per event. The methodologies will be expanded to yield annual cost and loss, for both the control and test groups, in terms of number of spraying operations or frost nights. The difference between these costs and losses is the annual benefit of the television dissemination of the SMS cloud cover images and related data to the growers comprising the sample. Procedures will be developed for extrapolating these results to other areas within the specific agricultural product industry where farming practices, weather occurrences, etc. seem similar.

Last, but not least, methods will be developed for the efficient manipulation of the large quantities of data which will be collected from both the growers and the National Weather Service.

6.4.2.2 Data Collection

The data collection task is concerned with gathering the necessary data, both current and historical, from growers and the National Weather Service. Based upon the procedures which are developed for data collection and the data collection forms, participating growers will be instructed in data collection methods and requirements. Continued

coordination will be maintained with the USDA and growers to assure the necessary data flow. It is anticipated that the primary interface with the growers during the data collection will be the USDA. It is extremely important that the farmers maintain careful and complete daily records as per the provided data forms. It is anticipated that a significant effort will have to be devoted to grower coordination to assure the necessary flow of accurate data.

An analysis will be performed to determine the availability of pertinent historical grower data for incorporation into the control group data base. Appropriate data will be collected. Based upon the data sources previously established, data will be collected on spot and future prices, chemical and fuel prices and other necessary data found to be common to all growers.

Continued coordination will be maintained with the National Weather Service to assure the necessary data flow. If it is found that grower historical data can be used as part of the control group, then historical forecast data and historical recorded event data will be collected. In any event, during the growing seasons included in the experiments, daily weather forecasts and daily observed weather events will be obtained from the National Weather Service.

During the conduct of the experiment, continued coordination will be maintained between ECON and Colorado State University. This coordination will result in ECON being appraised of changes in information content or format so that their impact on experiment results may be taken into account.

6.4.2.3 Data Reduction

The data reduction is concerned with the review of the collected data and transformation of the data into suitable form for entry into a general data base. As data is received, it will be reviewed for correctness and consistency. If problems are encountered, data forms and data collection procedures will be reviewed and altered accordingly.

Procedures will be developed which will "flag" possible inconsistencies in data. For example, current data will be compared with historical data and between similar farms, and data which seem questionable will be noted. The growers will then be contacted, through the USDA, to determine if indeed an error was made or data requirements were misinterpreted. This is particularly important during the early stages of data collection where it is anticipated that misunderstandings will exist and need rapid clarification.

The data reduction task is also concerned with the determination of the accuracy of forecasting of weather events which will impact farm operations and decisions of concern. In particular, it will be necessary to establish appropriate false alarm and miss statistics. This will be accomplished by utilizing the combination of NWS forecasts, NWS actual weather observations, and farmer observations which are to be collected as part of the economic experiment.

6.4.2.4 Economic Analysis

The economic analysis is concerned with the determination of annual savings which occurs as a result of the television dissemination of SMS cloud imagery and related information to growers and based upon the data obtained from growers and the National Weather Service. Cost

and loss per event will be established and segmented accordingly. The results of these computations will be reviewed with the growers, particularly during the early phases of data collection, in order to determine errors in methodology and/or input data and to maintain quality control throughout the data collection periods. Daily costs and losses will be established for each farmer and classified by event type, and farm type. At the end of each growing season (including historical seasons), average costs and losses will be determined so that annual costs and losses can be established for the control and test groups. The results of the control and test groups will be compared and the annual demonstrated savings (including dollar savings, fuel savings, and chemical savings) will be established. These savings, based upon the sample population, will be extrapolated to total industry annual savings, taking into account farm geographic locations, geographic weather patterns, farming practices, etc. The net result will be the establishment of demonstrated benefits and extrapolated (from the measured benefits) benefits which are the direct result of improved spraying decisions made possible by the television dissemination of the SMS cloud cover images and related data.

6.4.2.5 Econometric Modeling

The task of developing the econometric model illustrated in Figure 6.6 can be divided into two major subtasks: (1) estimation of social cost, and (2) estimation of economic benefit.

To estimate the social cost, it is necessary to collect, on a daily basis between July 1 and October 15, data on the acreage and location of fields burnt, and the level of air pollution, reported respiratory

troubles, particulars on patients (namely age, average income level, duration of illness, etc.) and medical service costs at a few urban areas like Portland, Eugene, etc. A stepwise multiple repression analysis will be performed on these data to establish the correlation between field burning and social costs.

To estimate the economic benefits it is necessary to collect data on production of grass seed, average cost of production per acre, level of inventory, short-term hedging contracts, long-term speculation future contracts, spot price, forecasts on future price, sale volume, market demand, export quota, etc. These data will be collected from Agricultural Extension Service, USDA, Commodities Market, and a sample population of producers. The data collection will be preceded by the development of the model so as to establish the relation among the various variables.

6.4.2.6 <u>Reporting</u>

Both oral briefings and written reports will be provided. Oral briefings will be given as required, however, it is anticipated that briefings will be given prior to the start of the 1978 growing season and will detail the experiment design and, in particular, the plans for control and test group data collection. Other briefings will be given at the completion of the data and economic analysis tasks associated with each growing season. Monthly activity reports will be provided. A detailed annual report will be provided at the end of each year. The annual report will describe in detail the methodology, the data collection techniques, the collected data (farmers, National Weather Service and others) and established results.

6.4.3 Schedule

The schedule for the Oregon Mixed Crop ASVT is detailed in Figure 6.8. It should be noted that the main body of the work starts in September 1977, and ends in June 1981. It has been indicated that the task of Econometric Modeling for grass field burning can start in September 1976. However, as an alternative arrangement this start can be shifted to September 1977 without any loss in the quality of the work, and without major effect on the overall budgetary requirements.

Data collection is planned for three consecutive growing seasons: 1978, 1979 and 1980. The data collected during 1978 will constitute the control group data. The same users will provide data during 1979 and 1980 which will constitute the test group data. The reason for collecting test group data on two seasons is that the growing season during 1979 will in all probability represent a transitional phase when users will start getting used to the introduction of the hourly television dissemination of weather information. The entire schedule is, of course, based on the assumption that the hourly television program of satellite data dissemination becomes operative in Oregon before the growing season of 1979 (i.e., March 1979) and after the growing season of 1978 (i.e., October 1978). If the television program gets shifted in time, the schedule of the experiment will also shift accordingly, the basic idea being that the control data will have to be collected over one growing season prior to the introduction of the television program and the test data will have to be collected over two growing seasons subsequent to the introduction of the television program. It should be noted that while the test group data are to be collected

over two growing seasons the control group data collection is suggested over only one growing season. It is certainly more desirable to collect the control group data also over two seasons prior to the introduction of the television program, because it increases the level of statistical confidence in the results associated with the control group. This would increase the span of the entire experiment to four years rather than three. However, for the sake of economy if the entire span of the experiment has to be curtailed, it is better to shorten the control group data collection to one season rather than curtailing the test group data collection to anything shorter than two seasons. This is because the control group data can at least partly be supplemented with historical data, whereas the test group data collected during the first season subsequent to the television program will represent only a transitional phase thereby necessitating at least another year of data collection to capture the steady state. Keeping all these in mind, it is being suggested that the experiment be continued over three growing seasons--one prior to and two subsequent to the introduction of the television program.

The schedule in Figure 6.8 delineates the various tasks outlined in Section 6.4.2. In general terms, the experiment design will take place during the later half of 1977 and the first half of 1978. Data collection will take place during March through October of 1978, 1979 and 1980. Data reduction and the economic analysis of the sampled data will cover approximately the same time periods. The benefit analysis and the extrapolation of benefits to all relevant growers will be done from December to April of 1979-80 and 1980-81.

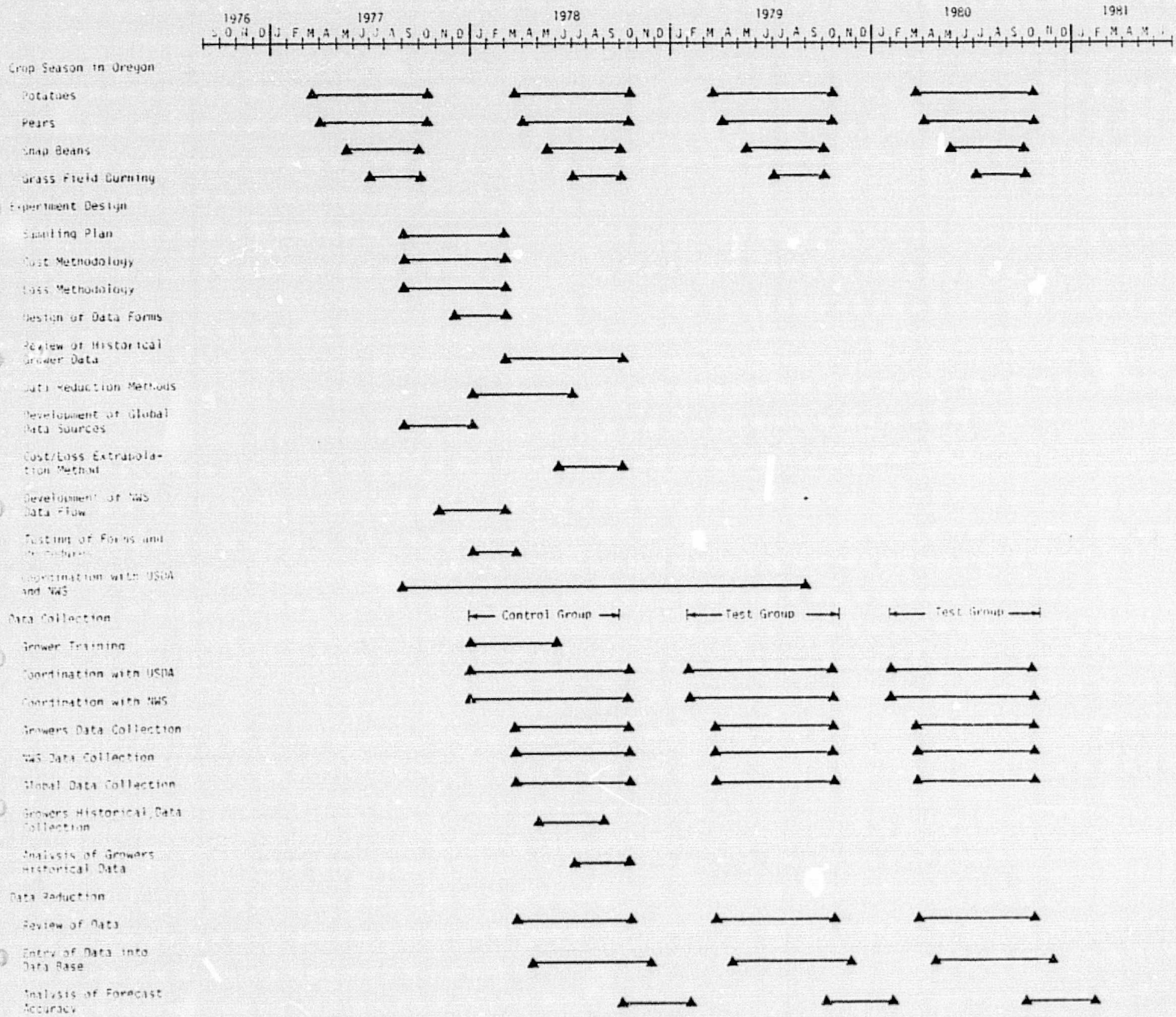

Figure 6.8 Schedule for Oregon Mixed Crop ASVT (Economic Experiment)

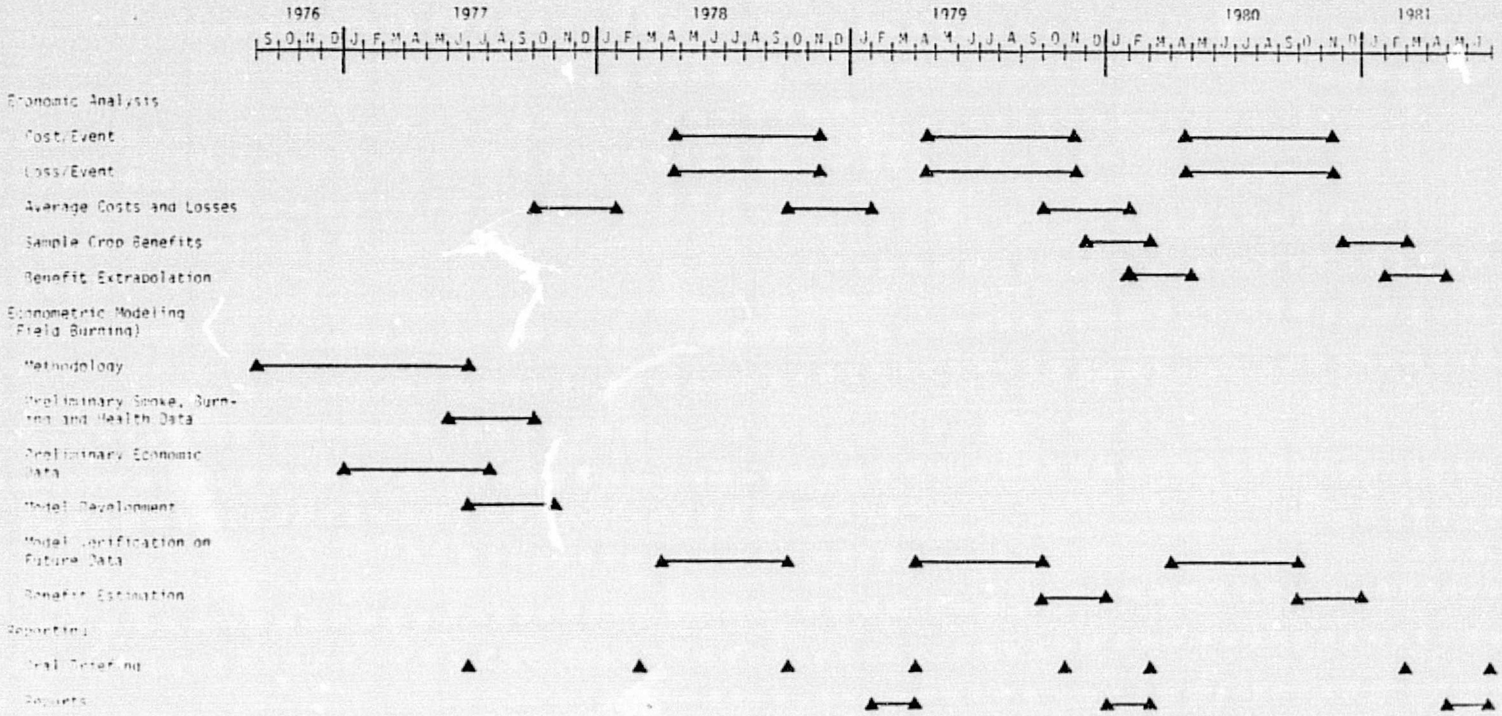

Figure 6.8 Schedule for Oregon Mixed Crop ASVT (Economic Experiment) (Continued)

Finally, the schedule indicates the timing of oral briefings and annual reports. Other briefings will be provided as required mainly to provide a feed-back mechanism to those who will be providing the data with patience and perserverence.

6.4.4 Management

The experiment will involve a large group of participants including NASA, ECON, Colorado State University, National Weather Service, USDA county agents, various growers associations and farmers in Oregon, Oregon State University, etc. Further, for the grass field burning experiment, the Department of Environmental Quality for the state of Oregon, a number of hospitals and clinics in smoke infested areas and the Smoke Management Program will provide important inputs.

The responsibility of ECON will include the design of the experiment, the specification of data requirements, participation in data collection with prescribed forms and the performance of economic analysis leading to the estimation of benefits due to improvement in the interpretation of meteorological phenomena brought about by the television dissemination of satellite data. ECON will also coordinate with USDA, NWS and various growers in order to assure an accurate and timely flow of data.

The meteorological data--both forecast as well as observation--will be provided by the National Weather Service. The various data on day-to-day activities, decisions, costs, losses, etc. will be provided to ECON (via the USDA) by the sample population of growers.

It is anticipated that both USDA county agents as well as the various growers associations will provide important interfaces between

ECON and the growers. They will provide general guidance to ECON in the areas of agricultural practices, methods, procedures, etc. for data collection and sample selection. They will also provide general coordination with, and education of the growers. In addition, USDA county agents will provide data forms to, and collect data from the growers.

Colorado State University, as part of the overall ASVT, will develop the basic television program formats and information content. As part of the economic experiment Colorado State University will keep ECON appraised of the basic broadcast formats and information content and changes during the course of the experiment.

Oregon State University will provide general consulting support to ECON in the relevant areas of Agro-economics.

In addition, for the grass field burning experiment, the Smoke Management Program and the Department of Environmental Quality will provide data on daily burning quotas and the level of pollution in urban areas like Portland, Eugene and Salem. Various hospitals and clinics will provide data on the health incidents and the associated costs.

NASA will provide general guidance to the participants in the experiment. In particular, NASA will direct the overall efforts of ECON and Colorado State University.

Because of the relatively large number of participants in the experiment and the need for continued coordination and review, it is recommended that a Coordination Working Group be established with each of the above organizations providing one member of the Working Group. It is recommended that the NASA representative serve as Chairman of the Working Group. The function of the Working Group would be

to provide responsible points of contact within each of the organizations who, in turn, would see that their organizations perform and cooperate as required. The Working Group would provide the mechanism for ironing-out difficulties or coordination. The frequency of meeting of the Working Group should vary depending upon the criticality of the efforts underway. For example, during the first several months it might be desirable to meet monthly, whereas during the latter part of the data collection phases and economic analysis phases, meetings might take place at three-month intervals. Once the experiment is initiated it is imperative, because the weather will not wait for men, that a smoothly functioning overall organization be established of highly dedicated people to insure the timely collection of data and the orderly flow of data.

6.4.5 Manpower Requirements and Budgetary Estimates

The anticipated manpower requirements are illustrated in Figure 6.9. Task 5, namely the econometric model for grass field burning is shown separately because in essence this task is a self-contained package different in nature from the rest of the tasks. The corresponding budgetary estimates are summarized in Table 6.16. The manpower estimates and the budgetary estimates do not include time which will be spent and costs which will be incurred by other participants in the experiment. They only reflect the participation of ECON. The role of the manpower is as follows:

- Project Director - Serve as the primary source of coordination with other participants in the experiment, direct the efforts of the technical staff involved in the design and conduct of the experiment, and participate in the design of the experiment.

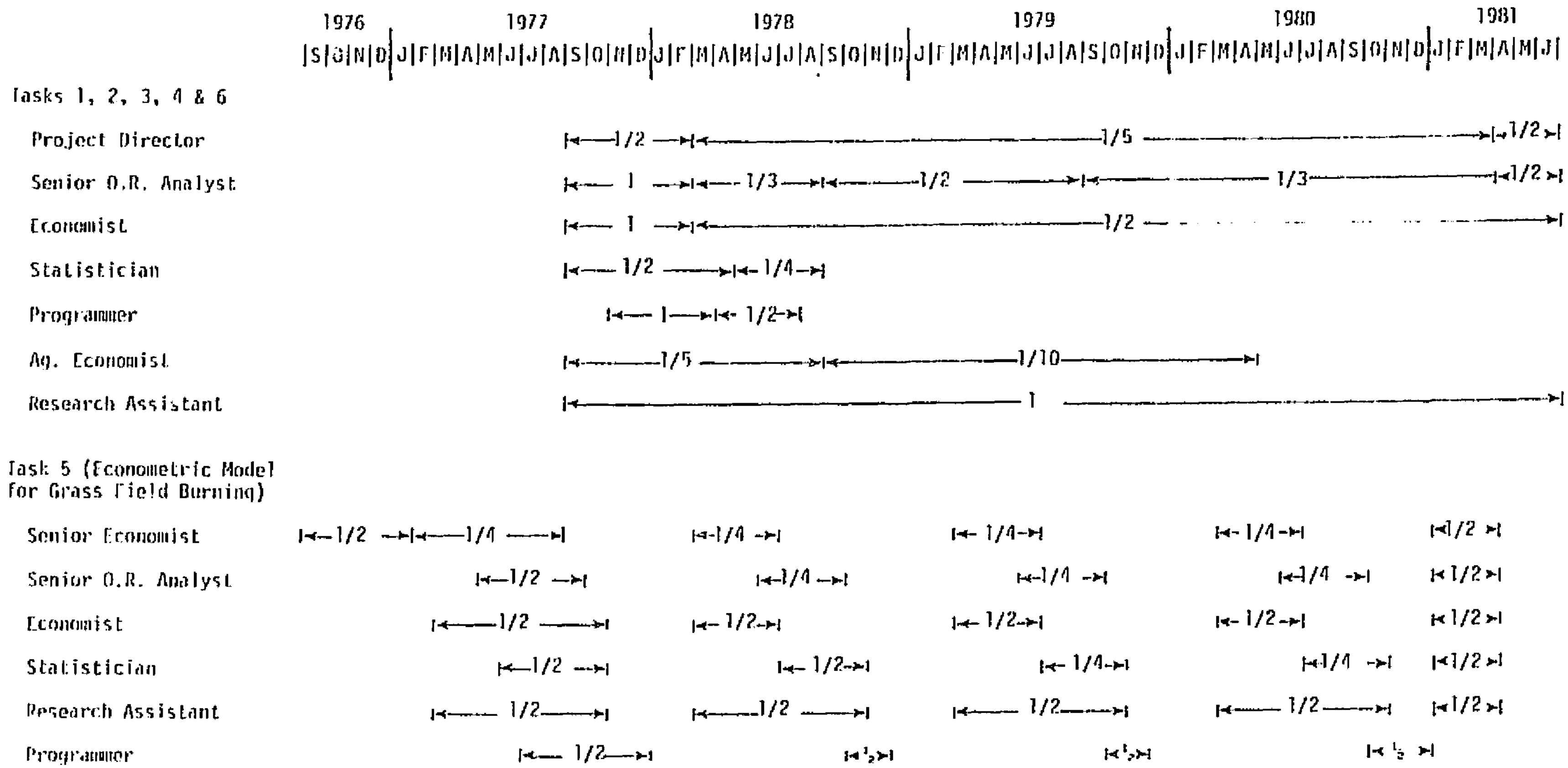

Figure 6.9 Manpower Projections For Oregon Mixed Crop ASVT (Economic Experiment) (Man Months/Month)

Table 6.16 Manpower Requirements (man-months/year) and Budgetary Estimates (K$/year)

Tasks 1, 2, 3, 4 & 6	9/76-8/77	9/77-8/78	9/78-8/79	9/79-8/80	9/80-8/81
Manpower					
Project Director		3.5-4.5	2-3	2-3	2-3
Senior O.R. Analyst		7-8	5-6	3-4	3.5-4
Statistician		4-5	--	--	--
Economist		8-10	5.5-6	6	5
Research Assistant		12	12	12	10
Programmer		6-8	--	--	--
Agricultural Economist		2-3	1-1.5	1-2	--
Total		42.5-50.5	25.5-28.5	24-27	20.5-22
Budget Estimates (K$/year)		200-240	120-135	110-125	95-105
Task 5					
Manpower					
Senior Economist	3.5-4.5	1-1.5	1	1-1.5	1-2
Senior O.R. Analyst	0.5-1	1	1-1.5	1	1-2
Economist	2.5-3	3-3.5	1	1	1.5
Statistician	1-2	2	1-2	0.5-1	2
Research Assistant	3	4	4	4	2.5
Programmer	1	2	1	1	1-2
Total	11.5-14.5	13-14	9-10.5	8.5-9.5	9-12
Budget Estimates (K$/year)	60-70	60-65	45-50	40-45	50-60

- Senior O.R. Analyst - Responsible for the detailed experiment design and day-to-day performance of the experiment; serve as the senior technical man on the project.

- Statistician - Participate in the formulation of the sampling plan and review of data.

- Economist - Participate in the development of the economic analysis methodologies and assist with data collection, data reduction and economic analysis.

- Research Assistant - Participate in the overall experiment design and assist with data collection, data reduction and economic analysis.

- Programmer - Responsible for the implementation of computer programs associated with the data reduction and economic analysis.

- Agricultural Economist - Provide general guidance pertaining to agriculture practices and economics.

With respect to Task 5, Econometric Modeling, the role of the indicated manpower is as follows:

- Senior Economist - Responsible for the formulation of the econometric model of the economic impacts which may result from the tapering production and marketing decisions.

- Senior O.R. Analyst - Responsible for the formulation of the econometric model of the social costs associated with the deterioration of air quality caused by field burning and the benefit brought about by improved forecast in way of improving the air quality.

- Economist - Participate in the development of the econometric models under the direct supervision of the Senior Economist. Perform the economic benefit assessments using the developed models.

- Statistician - Participate in the formulation of the sampling plan, review of data and statistical analysis.

- Research Assistant - Participate in the overall model development and assist with data collection, data reduction and economic analysis.

- Programmer - Responsible for the implementation of the econometric models.

The budget required to perform the tasks associated with the economic experiment (except grass field burning) is $200,000 to $240,000; $120,000 to $135,000; $110,000 to $125,000; and $95,000 to $105,000 for the years 1977-78, 1978-79, 1979-80 and 1980-81 respectively. The budget required to develop the econometric model for grass field burning is $60,000 to $70,000; $60,000 to $65,000; $45,000 to $50,000; $40,000 to $45,000; and $50,000 to $60,000 for the years 1976-77, 1977-78, 1978-79, 1979-80 and 1980-81 respectively. As indicated earlier, the task to be performed during 1976-77 can be shifted to 1977-78 without any loss of quality of the work. In that case the budget will be $120,000 to $135,000; $45,000 to $50,000; $40,000 to $45,000; and $50,000 to $60,000 for the years 1977-78, 1978-79, 1979-80 and 1980-81 respectively.

7. A RECOMMENDED TIME-PHASED PLAN

The scheduling of the economic experiment portion of the Florida, Mississippi and Oregon ASVTs must take into account several constraints, namely (1) the timing of pertinent crop planting, maintenance and harvesting activities, (2) the season weather patterns, and (3) the schedule for the commencement of distribution of new and/or improved weather related information. Figure 7.1 presents a recommended schedule for performing the Florida, Mississippi and Oregon economic experiments.* The combined timing of pertinent agricultural activities and weather events is indicated and represents the frost season in Florida (mid-November through March), the Mississippi cotton crop spraying season (mid-June through mid-October), and the frost and spraying seasons for pears (April through mid-September), the frost spraying and crop shearing seasons for potatoes (mid-March through mid-October), the spraying season for beans (May through August), and the grass burning season (mid-July through September) in the state of Oregon.

It is anticipated that the improved temperature and frost warning information will be distributed starting with the 1977-78 frost season in Florida. This dictates that, <u>if the Florida experiment is to be undertaken, the control group data collection must take place during the 1976-77 frost season</u>.

The Mississippi cotton crop economic experiment is the least constrained experiment since it is possible to establish concurrent control

*Note that the methodology and modeling development of the Oregon field burning experiment may be delayed approximately one year without jeopardizing the experiment.

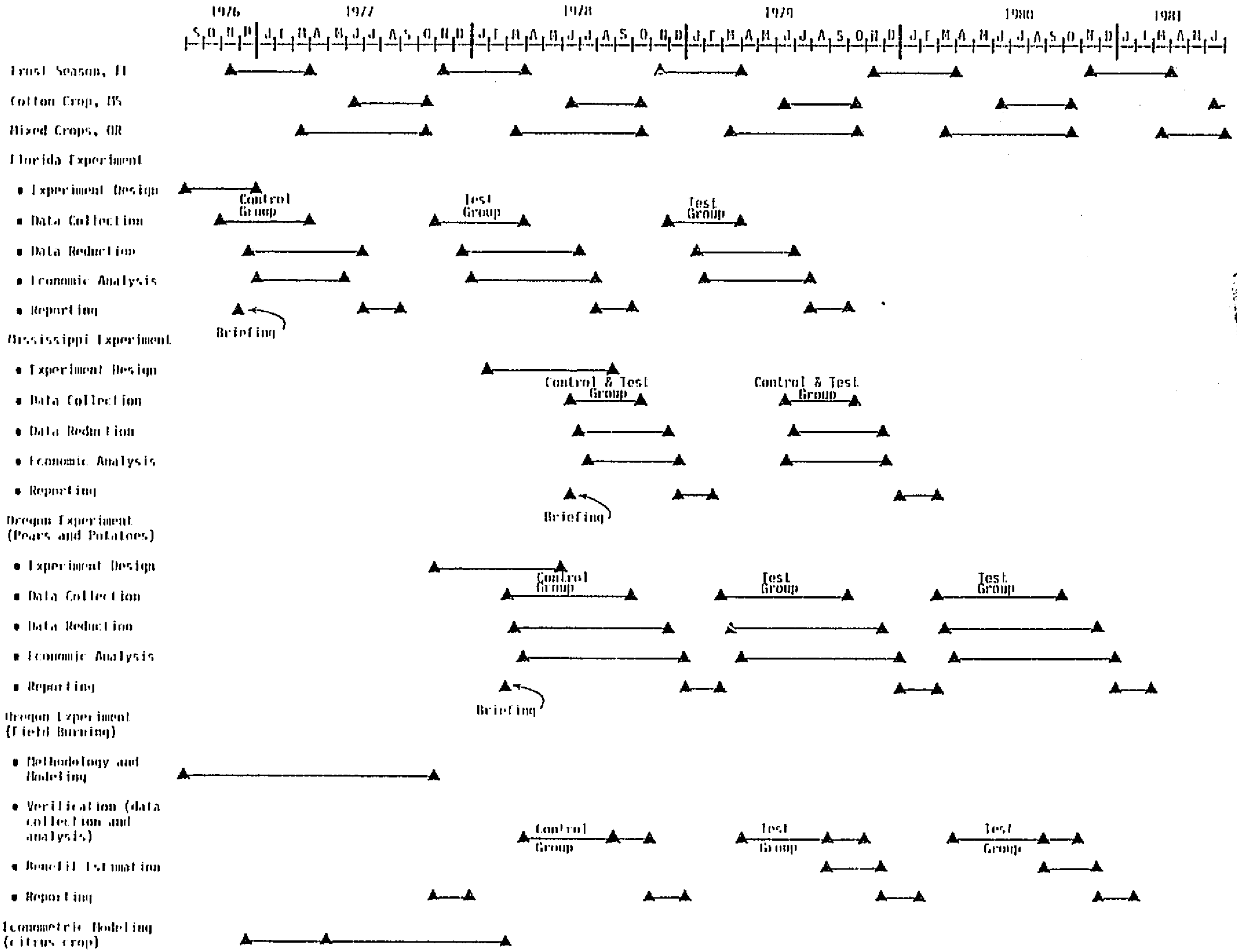

Figure 7.1 Recommended Schedule for Performing the Florida, Mississippi and Oregon Economic Experiments

(Arkansas) and test (Mississippi) groups. These groups can be established and data collection started any time after the television dissemination of SMS cloud imagery and related data has been initiated. The indicated plan is based upon an assumed starting date of mid-calendar year 1978. This implies that the Colorado State University television broadcasts will commence in Mississippi some time prior to this.

The Oregon economic experiment, as in the case of the Florida experiment, must get started approximately one year prior to the initiation of the television dissemination of SMS cloud imagery and related data. This is necessary so that control group data can be collected prior to the start of the television broadcasting. The indicated Oregon schedule is based upon the assumption that the television broadcasts will commence early in calendar year 1979.

Table 7.1 indicates the budget required to perform the Florida, Mississippi and Oregon economic experiments in accordance with the schedule illustrated in Figure 7.1. As mentioned above, the indicated Mississippi budgets can be adjusted in time and are independent of the timing of the start of television broadcasting except that the data collection must be accomplished after the broadcasting has been initiated. Both the citrus experiment in Florida and the mixed crop experiment in Oregon are critically tied to the time of television broadcasting since each must start data collection during the growing season which precedes the initiation of the television broadcasting.

Table 7.1 Budget Summary for Performing the Florida, Mississippi and Oregon Economic Experiments (K$/year)

ASVT	9/76-8/77	9/77-8/78	9/78-8/79	9/79-8/80	9/80-8/81
Citrus Industry (Fla.)	175 - 215	115 - 125	115 - 125	--	--
Cotton Growing (Miss.)	--	100 - 120	100 - 120	64 - 74	--
Mixed Crop (Oregon)*	--	200 - 240	120 - 135	110 - 125	95 - 105
Total	175 - 215	415 - 485	335 - 380	174 - 199	95 - 105
Econometric Modeling (Citrus Crop--Fla.)	40 - 43	36 - 45	--	--	--
Econometric Modeling and Experiment (Grass Burning--Oregon)	60 - 70+	60 - 65	45 - 50	40 - 45	50 - 60

*Not including the Oregon grass burning econometric modeling and experiment.

+This expenditure may be delayed by one year.

REFERENCES

1. Johnson, W.O., Minimum Temperatures in the Agricultural Areas of Peninsular Florida, Summary of 30 Winter Seasons 1937-67, IFAS Publication No. 9, 1970, University of Florida, Gainesville.

2. Florida Citrus Commission, Two Days in December, A Report on the Florida Freeze of 1962, Lakeland, Flordia.

3. Reuther, W., editor, The Citrus Industry, Vol. III, University of California, Division of Agricultural Science, Berkeley, California, Chapter 10.

4. Federal Crop Insurance Corporation, report data for 1975.

5. Cooper, W.C., and A. Peynado, Winter Temperatures of Three Citrus Areas as Related to Dormancy and Freeze Injury of Citrus Trees, Proc. Amer. Soc. Hort. Sci. 74:333-47, 1958.

6. Hendershott, C.H., The Responses of Orange Trees and Fruits to Freezing Temperatures, American Society for Horticultural Science Proceedings, Vol. 80 (1962), pp. 247-254.

7. Jackson, J.L., Cost of Cold Protection, Florida Cooperative Extension Service, University of Florida, IFAS, 1976.

8. Private Communications with Mr. James Georg, NWS and Mr. Paul Toft, NASA, KSC.

9. Cooper, W.C., R.H. Young, and F.M. Turrell, Microclimate and Physiology of Citrus: Their Relation to Cold Protection, Agr. Sci. Rev. 2(1):38-50, 1964.

10. Gerber, J.F. and J.D. Martsolf, Protecting Citrus From Cold Damage, AESUF, Circular 287, 1966.

11. Operations of the National Weather Service, U.S. Department of Commerce, NOAA, NSW, Silver Springs, Maryland, 1974.

12. Commercial Citrus Inventory, Florida Department of Agriculture, Florida Crop and Livestock Reporting Service, Orlando, Florida.

13. Florida Citrus Mutual, Annual Statistical Report, 1974-75 season, Lakeland, Florida.

14. Scope and Methods of the Statistical Reporting Service, U.S. Department of Agriculture, Miscellaneous Publication No. 1308, Washington, D.C., 1975.

15. Hayami, Y. and W. Peterson, Social Returns to Public Information Services: Statistical Reporting of U.S. Farm Commodities, American Economic Review, LXII, 1972.

16. Meyer, G., Editor, Mississippi Weather and Crop Report, Mississippi Crop and Livestock Report Services.

17. Pavin, D.W., et al, Cost of Production Estimates for Major Crops, Mississippi Delta, 1976, MIssissippi Agricultural and Forestry Experiment Station, Mississippi State University, Bulletin 843, April 1976.

18. 1976 Cost of Production, MAFES Bulletin 843.

19. Personal communications with Clifford E. Green, NWS Station Chief, Jackson and Frank Mukusky, NWS Station Chief, Little Rock, on May 10, 1976 and May 14, 1976 respectively.

20. Anon, Climatological Data--Mississippi, NOAA Environmental Data Service, Asheville, North Carolina, Volume 80, No. 10, October 1975.

21. Pavin, D.W., Jr., Cost of Production Estimates for Major Crops Mississippi Delta, 1976. Bulletin 843, MAFES, 1976.

22. Preemergence Weed Control in Cotton, Cooperative Extension Service, University of Arkansas and USDA, Leaflet 383 (Rev.), 1976.

23. Cotton Pest Management, Cooperative Extension Service, University of Arkansas and USDA, Leaflet 52 (Rev.) 1976.

24. Private Communication, Dr. Wayne Houston, Agronomist, MAFRS, July 2, 1976.

25. Private Communications, Dr. Mitchell, Entomologist, MAFRS, June 25 and June 30, 1976.

26. 1966-1975 Mississippi Weather And Crop Report.

27. Agricultural Statistics - 1973, U.S. Department of Agriculture.

28. Private Communication, Rufus Steinbeck, Cotton Farmer, Le Flore County, Mississippi, May 12, 1976.

29. 1976 Cost of Crops estimate.

30. Private Communication, Robert Frotisi, Cotton Farmer, Jefferson County, Arkansas.

31. Private Communication, Frank Makosky, Chief of Arkansas NWS Station, May 14, 1976.

32. Agricultural Development Division, Oregon Department of Agriculture, 1974 Oregon Agriculture.

33. Statistical Abstract of the United States - 1975, U.S. Department of Commerce.

34. Agricultural Experiment Station, Oregon State University, Corvallis, Agriculture: Its Importance to Oregon's Economy, Special Report 430, March 1975.

35. National Atlas of the United States of America.

36. U.S. Department of Commerce, NOAA, Federal Plan for a National Agricultural Weather Service, January 1971.

37. Oregon Department of Environmental Quality, Air Quality Control Division, Field Burning in the Willamette Valley - 1975, April 1, 1975.

38. Lambrecht, Frank, National Weather Service Annual Report on Fruit-Frost Activities, Medford District, Jackson County, Oregon, Spring 1976, U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

39. Conklin, Frank S., Adjusting to Air Quality Standards: A Contrast Between Grower and Industry Effects in Grass Seed Production, Oregon Agricultural Experiment Station Technical Paper 4255, Presented at the Sixty-Ninth Annual National Meeting of the Air Pollution Control Association, Portland, Oregon, July 1, 1976.

APPENDIX - A

ECONOMIC CONSIDERATIONS OF EXPERIMENT DESIGN

If the total population of users of improved information within a certain experiment is larger than the number which can be economically accommodated within the experiment, a sampling scheme has to be introduced to select the users that are to be included in the experiment. Under such circumstances, it is essentially the budgetary constraint that prevents the inclusion of the total population. Thus, the problem is to develop a sampling scheme which, within the limited budget, will yield maximum statistical confidence in the experimental result being representative of the result that would have been obtained had the total population been included in the experiment. In the language of statistics, this implies that the benefit estimate should be unbiased and that the variance of the estimate should be a minimum. Such a sampling scheme is presented here.

The cost of collecting experimental data from a particular sample will depend on the geographical location of the sample, the amount of data to be collected, and other such factors. However, it is possible to divide the entire user population into a finite number of strata where each stratum constitutes a collection of users each of whom would require an equal expenditure for incorporation into the experiment. Obviously, the data collection expenditure associated with members of one stratum are supposed to be different from the expenditure associated with members of another stratum. Under this assumption the

cost of running the experiment can be expressed as:

$$c = c_0 + \sum_i c_i \eta_i \tag{A-1}$$

where c is the overall cost,

c_0 is the start up cost,

i is the running index of the strata,

c_i is the cost associated with the incorporation of one sample belonging to the i^{th} stratum, and

η_i is the number of samples in the i^{th} stratum.

Let:

N_i be the total number of users (not samples) existing in the i^{th} stratum,

N be the total number of users in the entire population

B_{ij} be the benefit associated with the j^{th} user in the i^{th} stratum,

$\overline{B}_i$ be the average benefit of the i^{th} stratum where the average is calculated over all existing users in the i^{th} stratum, and

$\overline{b}_i$ be the sample mean benefit of the i^{th} stratum.

Thus

$$\overline{B}_i = \frac{\sum_{j=1}^{N_i} B_{ij}}{N_i} \tag{A-2}$$

and

$$\overline{b}_i = \frac{\sum_{j=1}^{\eta_i} B_{ij}}{\eta_i} \tag{A-3}$$

Note that $\overline{b}_i$ can be experimentally determined while $\overline{B}_i$ cannot, because not all users are included in the sample space.

The estimated average benefit of the entire population of existing users (not just samples) is given by:

$$\overline{B} = \frac{\sum_i N_i \overline{b}_i}{N} \tag{A-4}$$

Note that $\overline{B}$ is only an estimate of the overall benefit. The true mean of the actual benefits is given by:

$$B = \frac{\sum_i N_i \overline{B}_i}{N} \tag{A-5}$$

But B cannot be experimentally determined because, as mentioned earlier, $\overline{B}_i$ cannot be experimentally determined. In other words, the experiment leads to a value of $\overline{B}$ as expressed in Equation A-4, and this $\overline{B}$ is an estimate of B. However, the value of $\overline{B}$ is not unique. It depends on the samples chosen. Two experiments with two different sample populations will, in general, lead to two different values of $\overline{B}$. In this sense, $\overline{B}$ is a random variable with an associated probability distribution. The smaller the variance of $\overline{B}$, the greater the level of confidence of the result. Thus, the main thrust of the sampling problem is to determine that sampling scheme which leads to the minimum variance of $\overline{B}$ subject to the constraint that the overall cost c as expressed in Equation A-1 is fixed due to budgetary limits. The discussed sampling scheme may be determined by considering the following steps.

Step 1. If the overall experiment to measure the economic benefit is replicated a number of times, the value of $\overline{b}_i$ as expressed

in Equation A-3 will, in general, differ from one experiment to the next because it depends on the samples chosen. A sample population n_i can be chosen from a total population of N_i in $\binom{N_i}{n_i}$ number of ways, where the symbol $\binom{N_i}{n_i}$ represents the combination of N_i items taken n_i at a time. The claim is that the mean of these $\binom{N_i}{n_i}$ number of values of $\overline{b}_i$ is equal to $\overline{B}_i$ as expressed in Equation A-2. That is, in an unbiased experiment, the average value of all possible sample means is equal to the true mean.

Instead of giving a rigorous proof, the following illustration is given. Let A, B, C, D and E be five items out of which groups of three items are chosen. The following ten groups are possible: ABC, ABD, ABE, ACD, ACE, ADE, BCD, BCE, BDE and DCE. The mean of the five items is $\frac{1}{5}$ [A+B+C+D+E]. The mean of all the groups is given by:

$$\frac{1}{10}\left[\frac{A+B+C}{3}+\frac{A+B+D}{3}+\frac{A+B+E}{3}+\frac{A+C+D}{3}+\frac{A+C+E}{3}+\frac{A+D+E}{3}\right.$$
$$\left.+\frac{B+C+D}{3}+\frac{B+C+E}{3}+\frac{B+D+E}{3}+\frac{C+D+E}{3}\right]$$
$$=\frac{1}{30}\ [6(A+B+C+D+E]=\frac{1}{5}\ [A+D+C+D+E]$$

Thus, the mean of all the groups is equal to the mean of the parent population. This should apply in general, and hence

$$\mu\ (\overline{b}_i)=\overline{B}_i \tag{A-6}$$

where μ stands for mean and in statistical language, $\overline{b}_i$ is called an unbiased estimate of $\overline{B}_i$.

Step 2. Step 1 can be easily extended to the statement that $\overline{B}$, as expressed in Equation A-4, is an unbiased estimate of B of Equation A-5.

From Equation A-4,

$$\mu(\overline{B}) = \mu\left\{\frac{\sum_i N_i \overline{b}_i}{N}\right\}$$

$$= \frac{\sum_i [N_i \; \mu\,(\overline{b}_i)]}{N}$$

$$= \frac{\sum_i N_i \overline{B}_i}{N} \quad \text{[by Equation A-6]}$$

$$= B \text{ [by Equation A-5]} \qquad \text{(A-7)}$$

Step 3. The variance of $\overline{b}_i$ can be expressed as:

$$V(\overline{b}_i) = \mu\,[\overline{b}_i - \mu(b_i)]^2$$

$$= \mu\,[\overline{b}_i - B_i]^2 \qquad \text{[by Equation A-6]}$$

This, according to the standard results of Sampling Theory [1] can be expressed as

$$V(\overline{b}_i) = \frac{S_i{}^2\,(N_i - n_i)}{n_i\,N_i} = \frac{S_i{}^2}{n_i}\,(1 - f_i) \qquad \text{(A-8)}$$

where:

n_i and N_i are as explained in connection with Equations A-1 and A-2,

$$S_i{}^2 = \frac{\sum_{j=1}^{N_i} (B_{ij} - \overline{B}_i)^2}{N_i - 1} \quad \text{and}$$

$$f_i = \frac{n_i}{N_i}$$

Step 4. The variance of $\bar{B}$ can be expressed as:

$$V(\bar{B}) = \mu[\bar{B} - \mu(\bar{B})]^2$$

$$= \mu[\bar{B} - B]^2 \quad \text{[by Equation A-7]}$$

This, according to standard results of sampling theory [2] can be expressed as:

$$V(\bar{B}) = \frac{\sum_i N_i^2 V(\bar{b}_i)}{N^2} \tag{A-9}$$

Inserting Equation A-8 into Equation A-9, there results

$$V(\bar{B}) = \sum_i \frac{N_i^2 S_i^2 (1 - f_i)}{N^2 n_i} \tag{A-10}$$

Where S_i and f_i are as explained in connection with Equation A-8.

Step 5. Equation A-10 is an expression for $V(\bar{B})$ which has to be minimized subject to the budget constraint expressed in Equation A-1.

Equation A-1 can be rewritten as:

$$c_1 n_1 + c_2 n_2 + \dots + c_t n_t = c - c_0$$

where t is the total number of strata.

Also, Equation A-10 can be rewritten as:

$$V(\bar{B}) = \sum_{i=1}^{t} \frac{W_i^2 S_i^2}{n_i} - \sum_{i=1}^{t} \frac{W_i^2 S_i^2}{N_i}$$

where $W_i = \frac{N_i}{N}$

Using the calculus method of Lagrange Multipliers [3], the following expression is formed:

$$\sum_{i=1}^{t} \frac{W_i^2 S_i^2}{n_i} - \sum_{i=1}^{t} \frac{W_i^2 S_i^2}{N_i} + \lambda[c_1 n_1 + c_2 n_2 + \ldots + c_t n_t - c + c_0]$$

where λ is the Lagrangean.

Differentiating the above expression with respect to n_i yields

$$\lambda c_i - \frac{W_i^2 S_i^2}{n_i^2} = 0 \text{ (for } i = 1, 2, \ldots, t)$$

Thus,

$$n_i \sqrt{\lambda} = \frac{W_i S_i}{\sqrt{c_i}} \qquad \text{(A-11)}$$

Summing over all the strata,

$$n \sqrt{\lambda} = \sum_{i=1}^{t} \frac{W_i S_i}{\sqrt{c_i}} \qquad \text{(A-12)}$$

Taking the ratio between Equations A-11 and A-12 yields

$$\frac{n_i}{n} = \frac{W_i S_i}{\sqrt{c_i}} \Bigg/ \sum_{i=1}^{t} \frac{W_i S_i}{\sqrt{c_i}}$$

$$= \frac{N_i S_i \big/ \sqrt{c_i}}{\sum_{i=1}^{t} [N_i S_i \big/ \sqrt{c_i}]} \qquad \text{(A-13)}$$

where η_i is the number of samples to be selected in the i^{th} stratum,

η is the total number of samples,

N_i is the number of users in the i^{th} stratum,

S_i is the true variance of benefit in the i^{th} stratum, and

c_i is the marginal cost of incorporating one additional sample in the i^{th} stratum.

Equation A-13 provides a sampling scheme that minimizes $V(\overline{B})$ under the budget constraint. In order to implement the scheme, the value of η, as it appears in Equation A-13, has to be determined. This can be done by inserting the value of η_i from Equation A-13 into Equation A-1. Thus:

$$c = c_o + \frac{\eta \sum_{i=1}^{t} c_i N_i S_i / \sqrt{c_i}}{\sum_{i=1}^{t} [N_i S_i / \sqrt{c_i}\ ]}$$

or

$$\eta = \frac{(c-c_o) \sum_{i=1}^{t} [N_i S_i / \sqrt{c_i}\ ]}{\sum_{i=1}^{t} [N_i S_i / \sqrt{c_i}\ ]} \qquad \text{(A-14)}$$

Equation A-14 determines the total number of samples to be selected for the experiment. In order to determine the statistical significance of the result, Equation A-10 is used to evaluate the variance of $\overline{B}$. Assuming a normal distribution for $\overline{B}$, the standard confidence limits (i.e., 80 percent confidence within 2σ, 99 percent confidence within 3σ, etc.) can be obtained.

REFERENCES TO APPENDIX A

1. Cochran, W.G., Sampling Techniques, Wiley & Sons, 1967. page 22, Equations 2-8.

2. Ibid, page 90, Theorem 5.2.

3. Williamson R.E., Crowell R.H., Trotter H.F., Calculus of Vector Functions, Prentice-Hall, 1972, page 355, Theorem 1.2.

APPENDIX B

EXPERIMENTAL BENEFIT ASSESSMENT WITH DIFFERENT FORECAST CAPABILITIES FOR CONTROL AND TEST GROUPS

1. Introduction

In this section, an outline is presented of the methodology to quantify the incremental benefits that can be derived from improvements in weather information made available to users, where the improvements in the dissemination of weather information consists of showing up-to-date SMS and radar imagery of meteorological phenomena and interpreting such occurrences at regular intervals through television channels over and above the existing NWS weather forecast services. Thus the improvement is not to be defined in terms of a higher quality of NWS weather forecast. Rather, it is expected that if users, over and above their normal access to NWS, are also exposed, at frequent enough intervals, to television pictures showing meteorological phenomena like cloud movement, etc., they will be better able to anticipate for themselves the advent of weather events--both favorable as well as unfavorable--in their specific geographical locations of interest.

The incremental benefit to be computed is that portion which is attributable to the frequent broadcast of this television program, which, as mentioned above, consists of showing pictures of current meteorological occurrences.

The weather anticipation has to be made by the user himself with, of course, this additional tool at his disposal over and above the standard NWS forecast information that is already available to him. The baseline with respect to which this incremental benefit is to be computed is the level of benefit that he already derives from the NWS weather forecast service.

This methodology is based on the assumption that two mutually independent groups of users can be formed, one comprising the test group with access to the television program over and above the standard NWS forecast, and the other comprising the control group with access solely to NWS forecast. Further, it assumes that it is possible to perform an extended experiment to collect day-to-day data on the meteorological observations, meteorological forecasts of NWS and the activities undertaken by both the test and the control groups along with their associated costs incurred, and weather losses suffered as well as avoided. It is assumed at the moment that such an experiment will be performed involving cotton growers and maybe soybean growers in Mississippi. However, it should be emphasized that the methodology outlined here is not restricted to cotton growers in Mississippi; it can be applied to any user group as long as it is feasible to perform the experiment outlined above. Further, a method is suggested to extend the results obtained from an experiment involving a particular user group to a nationwide benefit estimation involving similar users across the nation. The benefit is defined in terms of the present worth of a series of cost reductions to the users made possible through the broadcasts of the television program. There are standard methods of translating these dollar benefits to the utility payoffs, which constitute an alternative definition of benefit. Yet another way to define a benefit is in terms of producer surplus and consumer surplus that ultimately result from the cost reduction mentioned above. Given a certain cost reduction, these producer and consumer surpluses can be readily calculated from the demand curve and the supply curve of the commodity in question. However, these alternative definitions of benefit are left out because they do not influence the methodology.

2. Layout of Experimental Data Selection Scheme

The objective of the experiment is to calculate the benefit (as defined above in terms of present worth of savings due to cost reduction) attributable to the television program consisting of broadcasting and interpreting the SMS and radar imagery of meteorological phenomena.

Thus, the layout of the data selection scheme should be such that the necessary and sufficient set of data can be collected so as to calculate the said benefit. This data collection selection scheme consists of the following steps:

2.1 Identification of Test Group

A significant sample of users has to be identified having access to the television program. If the experiment consists of cotton growers in the Mississippi Delta, the growers in the State of Mississippi will constitute this group if the present plan of television coverage in the whole State of Mississippi is implemented. The same will apply for growers of soybean which is the other most important crop in Mississippi. The sample of growers should be carefully chosen so as to represent the various farm sizes, the various soil types and the various production techniques, including crop rotation and the mix of labor and machinery. In other words, the sample of growers chosen for the study should be representative of the entire spectrum of variations that exists among the farms.

2.2 Identification of the Control Group

The control group should consist of users that are identical, as far as possible, to the test group with the only exception that the control group will not have any access to the television program. If growers in

the State of Mississippi are chosen to comprise the test group, similar growers in Arkansas and Louisiana may constitute the control group. Further, if partial data collection can be started with immediate effect, the growers in Mississippi also can form the test group till such time as it is feasible for the television program to start in Mississippi. Also, if historical data for the growers of Mississippi, along with the weather forecast and observation data, are available in sufficient detail, this historical data can constitute the control group.

2.3 Identification of Critical Weather Events

It is difficult to single out any specific weather event that most critically affects the user. Usually it is a combination of weather phenomena that determines whether the weather condition is adverse or favorable. For example, the farmer who is concerned as to whether he should irrigate the soil is interested in having forecasts on temperature, precipitation, soil moisture content, humidity, etc. Each of these variables, as it were, is a dimension in a multi-dimensional vector space. A certain region in this space defines the favorable weather condition, and the complement of that region defines the unfavorable weather condition. Thus, it is necessary to define the boundaries of the favorable regions corresponding to the users' activities. Table B.1 illustrates such a list for agricultural activities and their corresponding ranges of favorable weather.

It should be emphasized that Table B.1 is only of a very general nature. For a specific industry like cotton growing or soybean growing, specific tables similar in nature to Table B.1 have to be compiled. For each operation listed in Table B.1 there is a corresponding lead time needed by the grower to take a protective action if adverse weather is expected. It is

Table B.1 Favorable Weather Conditions for Agricultural Operations

Operation	Soil Moisture	Soil Temperature	Air Temperature	Precipitation	Wind Velocity	Dew	Humidity
1. Soil Preparation	<80%	>32°F	—	<.05"	<30mph	—	—
2. Soil Fumigation	40%-80%	55°-80°	—	<.01"	<20mph		
3. Planting	40%-80%	>40°F	—	<.05"	<20mph	—	—
4. Transplant (Succulents)	60%-90%	>50°F	>28°F	<.05"	<15mph	—	—
5. Transplant (woody)	>80%	32°F-50°F	<50°F	<.05"	<30mph	—	—
6. Crop Fertilization	30%-80%	<50°F	—	<.05"	<30mph	—	—
7. Crop Cultivation	60%-90%	—	—	<.05"	<30mph	—	—
8. Spraying	<90%	—	—	0	<10mph	pressure & duration	
9. Irrigation	<50%		max.& min.	0	<30mph		
10. Freeze Protection	—		<32°F		direction & speed		
11. Harvesting	<90%	—	—	0	5-20mph	pressure & duration	<75%
12. Livestock Protection	—		<40°F & >85°F	>.05"	>25mph		—
13. Livestock Watering	—	—	<20°F	<.5"	—		—

Source: Federal Plan for a National Agricultural Weather Service, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, January, 1971.

necessary to establish that lead time for each operation. There may be some operations for which short-term forecast is of no consequence. For example, in some parts of San Jacquin Valley in California, irrigation water is available once in fifteen days. Thus, unless exact forecast for 15 days is available, the farmer can be expected to purchase the water when available rather than to take his chances that there will be enough rain in the next 15 days to make the purchase water redundant. Such operations have to be excluded from the benefit analysis.

3. Compilation of Data Base

The data base should contain the following data:

1. Complete list of users in both the test as well as the control group, along with the volume of industry associated with each user. In the case of cotton or soybean growers, the volume can be expressed in terms of acreage cultivated.

2. Each grower's operation on a daily basis. This can be compiled in terms of yes/no entries against the list of possible operations (similar to those listed in Table B.1). This should apply to both the test group and the control group.

3. The cost factor associated with each of the above mentioned operations. In the case of cotton growers, it can be expressed in terms of dollars per acre per day of a certain activity.

4. Each NWS forecast, along with the time the forecast is made, in both the test and control zones. For each forecast, each user within the experimental population, both in the control as well as in the test group, will be expected to provide the following data:

   a. A yes/no answer to whether on receiving the weather related information the user believes the NWS weather forecast. A yes/no type of answer is being recommended because it is felt that in real life it can be expected that the user cannot always assign a meaningful probability to the anticipated weather occurrences.

b. If the user believes that the weather will be favorable, then two possibilities may arise--either he undertakes one of the regular activities (e.g., planting, fertilization, harvesting, etc.) which has a certain cost associated with it, or he may not undertake any activity, because either there is nothing to be done or there exists some other constraint (e.g., lack of manpower or machinery, budget constraints, etc.) Both these possible cases are to be reported along with the cost of undertaking an activity and the reason and the anticipated loss, if any, of not undertaking the regular activity.

c. If the user believes that the weather will be adverse, then three possibilities arise. First, he may take a protective action (including a deferment of the normal schedule). Secondly, it may be that he cannot take a protective action because he gets too short a notice. Lastly, there may be any number of reasons, including organizatinal constraints, lack of motivation to protect because the cost of protection outweighs the expected saving to be accomplished thereby, etc. All the three possible cases are to be reported along with cost of taking the protective action and anticipated loss in case the protective action is not taken.

5. Actual weather condition during the interval covered by each forecast in both the control and the test zones. This weather condition is to be described as either favorable or unfavorable in the sense that critical weather events have been described above. Thus, in case the weather condition is observed as favorable with respect to a certain action, it implies that all the relevant weather events (viz. precipitation, wind velocity, humidity, etc.) are within the range of tolerance. In case the weather condition is observed as unfavorable, it follows that at least one of the regular components is outside the range of tolerance. The measurements of these components are to be recorded.

Thus, the data base should contain the following data points per user on a per-day basis:

a. NWS forecast,

b. User's faith in the forecast,

c. User's activity,

d. Observation of actual weather, and

e. User's expenses and weather losses (if any) per day per acre.

All possible combinations of the first four components are illustrated in a flow chart in Figure B.1.

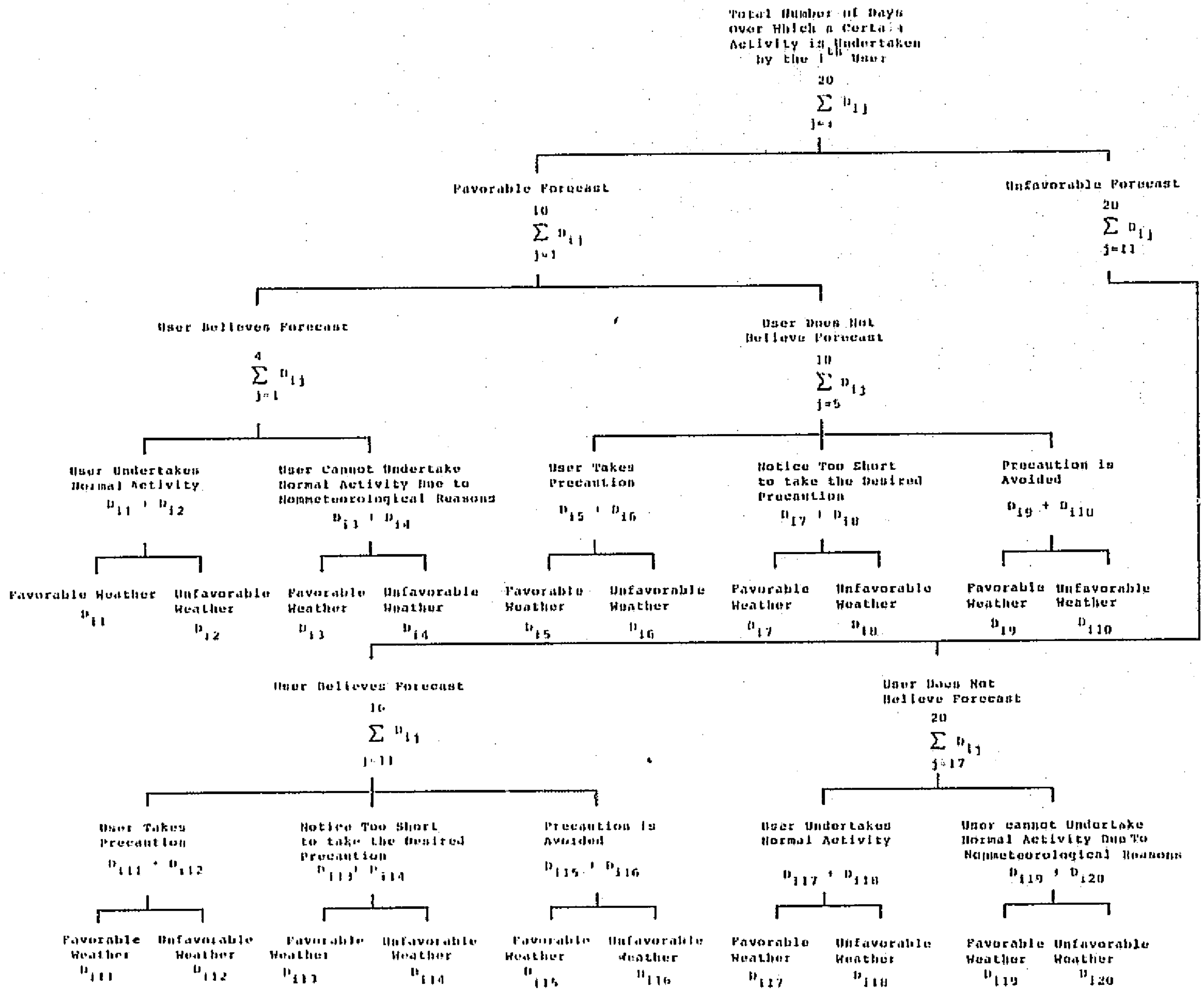

Figure B.1 Flowchart of User Activity With Respect to Meteorological Forecast and Observation

The flowchart is self-explanatory. There are twenty different possibilities for user i, as illustrated by D_{ij}, as j goes from 1 to 20. As for elucidation, D_{i1} for a certain activity of user i is the number of days over which the forecast is favorable for that activity, the user believes the forecast, he undertakes normal activity; and the day turns out to be favorable. Let the average expenditure incurred per acre per day during D_{ij} days (i.e., average cost per acre or loss per acre per day) be expressed as E_{ij}. In order to distinguish between the control group and the test group, the variables associated with the control group are primed. In other words, D_{ij} and E_{ij} correspond to the i^{th} user in the test group, and D'_{ij} and E'_{ij} correspond to the i^{th} user in the control group. The data collection scheme essentially consists of compiling D_{ij}, E_{ij}, D'_{ij} and E'_{ij} for each i and j under each activity.

4. Benefit Computation

Assuming that the data, as indicated in the previous section, are gathered, the task is to compute the benefit associated with the television program. It should be noted that this benefit, in general, will not be the simple difference between the expenses incurred by the test group and the control group. This is because, though the two groups are very similar by selection, the weather occurrences and the forecast qualities between the two groups will not necessarily be identical. Further, there are certain expenditures that a user is apt to incur that are not related to any meteorological reasons, e.g., a machine that is out of order. Expenses such as these should not be included in the benefit computation. Thus, the benefit computation consists of two steps. First, the expenses incurred by the control group have to be translated to the expenses that would have been

incurred by the control group if the occurrence of weather events and the quality of the NWS forecast in the control group had been identical with the weather events and the forecast quality (excluding the television program) in the test group. This translation brings the expenses to, as it were, a common denominator, and, as such, let us define them as the normalized values of the control variables. Secondly, the expenses incurred due to non meteorological reasons have to be subtracted out. The benefit associated with the television program is the difference between expenses of the test group (excluding the non meteorological expenses) and the normalized expenses of the control group as explained above.

This normalization of the expenses of the control group can be accomplished as follows. Table B.2 is a tabulated presentation of some of the information contained in Figure B.1. Let N and N′ be the total number of days spent on the activity in question by the i^{th} users in the test group and control group respectively. Also, let W and W′ be the number of days that the weather has been unfavorable during the activity of the i^{th} users in the test and control group respectively. Further, define the variables X, Y, U, V, A, B, G, H and their corresponding primed variables as indicated in Table B.2. Note that since the data collection scheme contains the enumeration of D_{ij} as j goes from 1 to 20, the variables defined in Table B.2 can be easily calculated for the control group as well as the test group. In terms of these variables, the following equations can be introduced directly.

$$N \equiv X + Y + U + V + A + B + G + H \equiv \sum_{j=1}^{20} D_{ij} \tag{1}$$

$$W \equiv A + B + G + H \tag{2}$$

$$\beta \equiv \text{Forecaster's Miss} = \frac{A+B}{X+Y+A+B} \tag{3}$$

$$\alpha \equiv \text{Forecaster's False Alarm} = \frac{U+V}{U+V+G+H} \tag{4}$$

Table B.2 Grouping of Forecast, User's Belief and Weather Occurrence

Forecast	User's Belief	Weather Occurrence	Number of Days in Test Group	Number of Days in Control Group
Favorable	Favorable	Favorable	$X = D_{i1} + D_{i3}$	$X' = D'_{i1} + D'_{i3}$
Favorable	Unfavorable	Favorable	$Y = D_{i5} + D_{i7} + D_{i9}$	$Y' = D'_{i5} + D'_{i7} + D'_{i9}$
Unfavorable	Favorable	Favorable	$U = D_{i17} + D_{i19}$	$U' = D'_{i17} + D'_{i19}$
Unfavorable	Unfavorable	Favorable	$V = D_{i11} + D_{i13} + D_{i15}$	$V' = D'_{i11} + D'_{i13} + D'_{i15}$
Favorable	Favorable	Unfavorable	$A = D_{i2} + D_{i4}$	$A' = D'_{i2} + D'_{i4}$
Favorable	Unfavorable	Unfavorable	$B = D_{i6} + D_{i8} + D_{i10}$	$B' = D'_{i6} + D'_{i8} + D'_{i10}$
Unfavorable	Favorable	Unfavorable	$G = D_{i18} + D_{i20}$	$G' = D'_{i18} + D'_{i20}$
Unfavorable	Unfavorable	Unfavorable	$H = D_{i12} + D_{i14} + D_{i16}$	$H' = D'_{i12} + D'_{i14} + D'_{i16}$

$\zeta \equiv$ Fraction of Time User Believes Favorable Forecast $= \frac{X+A}{X+Y+A+B}$ (5)

$\xi \equiv$ Fraction of Time User Believes Unfavorable Forecast $= \frac{V+H}{U+V+G+H}$ (6)

$\mu \equiv$ Rate of Miss, Given a Favorable Forecast Believed by User $= \frac{A}{X+A}$ (7)

$\nu \equiv$ Rate of False Alarm, Given an Unfavorable Forecast Believed by User $= \frac{V}{V+H}$ (8)

The corresponding primed variables for the control group can be similarly defined. With a little algebraic manipulation, equations (1) through (8) can be inverted such that, given N, W, β, α, ζ, ξ, μ, ν, the values of X, Y, U, V, A, B, G and H can be determined as expressed in equations (9) through (16).

$$X = \left[\frac{(1-\alpha)N-W}{1-\alpha-\beta}\right](1-\mu)\zeta \qquad (9)$$

$$Y = \left[\frac{(1-\alpha)N-W}{1-\alpha-\beta}\right][1-\beta-(1-\mu)\zeta] \qquad (10)$$

$$U = \left[\frac{W-N\beta}{1-\alpha-\beta}\right][\alpha-\nu\xi] \qquad (11)$$

$$V = \left[\frac{W-N\beta}{1-\alpha-\beta}\right]\nu\xi \qquad (12)$$

$$A = \left[\frac{(1-\alpha)N-W}{1-\alpha-\beta}\right]\mu\zeta \qquad (13)$$

$$B = \left[\frac{(1-\alpha)N-W}{1-\alpha-\beta}\right][\beta-\mu\zeta] \qquad (14)$$

$$G = \left[\frac{W-N\beta}{1-\alpha-\beta}\right][1-\alpha-\xi(1-\nu)] \qquad (15)$$

$$H = \left[\frac{W-N\beta}{1-\alpha-\beta}\right][1-\nu]\xi \qquad (16)$$

At this point, the question is what would be the values of X', Y', U', V', A', B', C' and H' if N', W', α' and β' were made identical to N, W, α and β respectively. Let these normalized values be denoted as X^*, Y^*, U^*, V^*, A^*, B^*, G^* and H^* respectively. In the same vein, let ζ^*, ξ^*, μ^* and ν^* be the normalized values of ζ', ξ', μ' and ν' respectively. It should be noted that ζ^*, ξ^*, μ^* and ν^* will, in general, not be equal to ζ, ξ, μ, and ν. This is because, though the NWS forecast quality of the control group is being translated into the NWS forecast quality of the test group, the test group is provided with an additional service, <u>viz</u>., the television program which is intended to assist the user in anticipating the correct weather. It is precisely the respective differences between ζ, ξ, μ, ν and ζ^*, ξ^*, μ^*, ν^* to which the benefit due to the television program, if any, is directly attributable.

At this point, it is assumed that the following relations hold at least over a small range:

$$\frac{1-\zeta^*}{\beta} = \frac{1-\zeta'}{\beta'} \tag{17}$$

$$\frac{1-\xi^*}{\alpha} = \frac{1-\xi'}{\alpha'} \tag{18}$$

$$\frac{\mu^*}{\beta} = \frac{\mu'}{\beta'} \tag{19}$$

$$\frac{\nu^*}{\alpha} = \frac{\nu'}{\alpha'} \tag{20}$$

Note that by the definition of the problem, $\alpha^* \equiv \alpha$ and $\beta^* \equiv \beta$. The rationale behind the above equations is as follows. A user may disbelieve a favorable weather forecast if his intuition tells him that the weather will

be unfavorable, and if he has reasonable evidence to see that the forecast is not free from miss errors. If the percentage of miss in weather forecast tends to zero, the user may choose not to disbelieve a good weather forecast in spite of his intuition suggesting otherwise. On the other hand, if the percentage of miss is very high, he may choose to more often disbelieve the good forecast and follow his intuition. Thus over a small range, it may be reasonable to assume that $(1-\zeta)$ is proportional to β, which leads to equation (17). A similar reasoning leads to the assumption that $(1-\xi)$ is proportional to α, and this is contained in equation (18). In order to justify equation (19), note that the number of days that favorable forecast is believed by the user in the control group is given by $X' + A'$ in Table B.2. If the probability of the forecaster's miss were uniformly distributed over all favorable forecast days, the number of misses over the favorable forecast days believed by the user would have been $(X' + A')\beta'$. Instead, such misses as shown in Table B.2 are given by A' which, according to equation (7) is given by $(X' + A')\mu'$. The reason for this apparent discrepancy is that the user acts as a "filter" which converts the uniform probability density function. Assuming that the characteristics of this "filter" remain the same, it follows that the ratio between $(X' + A')\beta'$ and $(X' + A')\mu'$ remains the same. This leads to equation (19). Similar arguments can be made for the justification of equation (20).

Equations (17) through (20) can be used to evaluate ζ^*, ξ^*, μ^*, and ν^* in terms of ζ', ξ', μ', ν', α, α', β and β' which, in turn can be calculated using equations (3) through (8). Now, inserting the values of N, W, α, β, ζ^*, ξ^*, μ^* and ν^* in equations (9) through (16), the values of X^*, Y^*, U^*, V^*, A^*, B^*, G^* and H^* can be directly computed. As mentioned

above, these denote the various distributions of forecast, user's belief and weather occurrence that would have occurred in the control group if the forecast quality and the actual weather occurrence in the control had been identical with the forecast quality (excluding television program) and the weather occurrence of the test group.

The next step is to discard the irregularities due to non-meteorological reasons. To make a fair comparison, it is necessary to assume that these irregularities occur with the same frequency both in the test as well as the normalized control group. Thus, it follows from Figure B.1 that the values of D_{i3}, D_{i4}, D_{i9}, D_{i10}, D_{i15}, D_{i16}, D_{i19}, D_{i20}, as observed in the case of the test group are to be kept unchanged in the normalized control group. At this point, using Table B.2, the following equations can be written:

$$
\begin{aligned}
D^*_{i1} &= X^* - D_{i3} \\
D^*_{i2} &= A^* - D_{i4} \\
D^*_{i3} &= D_{i3} \text{ (as previously explained)} \\
D^*_{i4} &= D_{i4} \\
D^*_{i9} &= D_{i9} \\
D^*_{i10} &= D_{i10} \\
D^*_{i15} &= D_{i15} \\
D^*_{i16} &= D_{i16} \\
D^*_{i17} &= U^* - D_{i19} \\
D^*_{i18} &= G^* - D_{i20}
\end{aligned}
\tag{21}
$$

$$D^*_{i19} = D_{i19}$$

$$D^*_{i20} = D_{i20}$$

Note that the values of D^*_{i5}, D^*_{i6}, D^*_{i7}, D^*_{i8}, D^*_{i11}, D^*_{i12}, D^*_{i13} and D^*_{i14} are yet to be determined. From Table B.2, it follows that

$$\begin{aligned} D^*_{i5} + D^*_{i7} &= Y^* - D^*_{i9} \\ &= Y^* - D_{i9} \text{ (from equation 21).} \end{aligned} \tag{22}$$

Similarly,

$$\begin{aligned} D^*_{i6} + D^*_{i8} &= B^* - D^*_{i10} \\ &= B^* - D_{i10} \end{aligned} \tag{23}$$

$$D^*_{i11} + D^*_{i13} = V^* - D_{i15} \tag{24}$$

$$D^*_{i12} + D^*_{i14} = H^* - D_{i16} \tag{25}$$

At this point, the following assumption are made

$$\frac{D^*_{i5}}{D^*_{i6}} = K \cdot \frac{D'_{i5}}{D'_{i6}} \equiv P \tag{26}$$

$$\frac{D^*_{i7}}{D^*_{i8}} = K \cdot \frac{D'_{i7}}{D'_{i8}} \equiv Q \tag{27}$$

$$\frac{D^*_{i11}}{D^*_{i12}} = L \cdot \frac{D'_{i11}}{D'_{i12}} \equiv R \tag{28}$$

$$\frac{D^*_{i13}}{D^*_{i14}} = L \cdot \frac{D'_{i13}}{D'_{i14}} \equiv S \tag{29}$$

where:

$$K = \frac{[\beta' - \mu'\zeta'] \cdot [1-\beta-(1-\mu^*)\zeta^*]}{[\beta-\mu^*\zeta^*] \; [1-\beta'-(1-\mu')\zeta']}$$

$$L = \frac{\nu^*[1-\nu']}{\nu'[1-\nu^*]}$$

and P, Q, R and S are known constants as defined by these equations.

The rationale for the above assumptions is as follows. From Table B.2, the number of good weather forecasts that the user in the control group does not believe is given by $Y' + B'$, out of which Y' turns out to be favorable and B' turns out to be unfavorable. From equations (10) and (14)

$$\frac{Y'}{B'} = \frac{1-\beta'-(1-\mu')\zeta'}{\beta'-\mu'\zeta'} \tag{30}$$

The corresponding ratio for the normalized control group is given by:

$$\frac{Y^*}{B^*} = \frac{1-\beta-(1-\mu^*)\zeta^*}{\beta-\mu^*\zeta^*} \tag{31}$$

If the ratio $\frac{Y'}{B'}$ had been uniformly distributed among the three possible ensuing situations (see Figure B.1).

$$\frac{D'_{i5}}{D'_{i6}} \quad , \quad \frac{D'_{i7}}{D'_{i8}} \quad , \quad \frac{D'_{i9}}{D'_{i10}}$$

would have been equal to $\frac{Y'}{B'}$.

However, the distribution of $\frac{Y'}{B'}$ is, the general, not expected to be uniform as will be indicated by different numerical values of

$\frac{D_{i5}}{D_{i6}}$, $\frac{D_{i7}}{D_{i8}}$, and $\frac{D_{i9}}{D_{i10}}$.

It is being assumed that their relative weightings remain the same in the normalized control situation. Equations (26) and (27) thus directly follow from this assumption. Similar justification applies for Equations (28) and (29).

New Equations (22) through (29) can be solved for D^*_{i5}, D^*_{i6}, D^*_{i7}, D^*_{i8}, D^*_{i11}, D^*_{i12}, D^*_{i13} and D^*_{i14} with the following results:

$$D^*_{i5} = \frac{P}{P-Q} \left[Y^* - D_{i9} - Q(B^* - D_{i10})\right]$$

$$D^*_{i6} = \frac{1}{P-Q} \left[Y^* - D_{i9} - Q(B^* - D_{i10})\right]$$

$$D^*_{i7} = \frac{Q}{P-Q} \left[P(B^* - D_{i10}) - Y + D_{i9}\right]$$

$$D^*_{i8} = \frac{1}{P-Q} \left[P(B^* - D_{i10}) - Y^* + D_{i9}\right]$$

$$D^*_{i11} = \frac{R}{R-S} \left[V^* - D_{i15} - S(H^* - D_{i16})\right]$$

$$D^*_{i12} = \frac{1}{R-S} \left[V^* - D_{i15} - S(H^* - D_{i16})\right]$$

$$D^*_{i13} = \frac{S}{R-S} \left[R(H^* - D_{i16}) - V^* + D_{i15}\right]$$

$$D^*_{i14} = \frac{1}{R-S} \left[R(H^* - D_{i16}) - V^* + D_{i15}\right]$$

where P, Q, R and S are as defined in Equations (26) through (29). Equations (21) and (32) give the complete description of the normalized control group.

The expenses incurred by the $i^{\underline{th}}$ user for a certain activity is given by:

$$C_i = \sum_{j=1}^{20} D_{ij} \, E_{ij} \qquad (33)$$

Where E_{ij}, as previsously defined, stands for the average expenditure incurred per day per acre during D_{ij} days. Similarly, the expenses incurred by the $i^{\underline{th}}$ user in the normalized control group are given by:

$$C_i^* = \sum_{j=1}^{20} D_{ij}^* \, E_{ij} \qquad (34)$$

where D_{ij}^* for all values of j are expressed in Equations (21) and (32).

The benefit derived from the television program by the $i^{\underline{th}}$ user over a certain activity is $C_i^* - C_i^*$. The total benefit is the summation over all i and all activities. Note that the expenses incurred on certain days due to non meteorological reasons automatically cancel out when C_i is subtracted from C_i^*, because the number of such days in the normalized control group has been made identical with those for the test group.